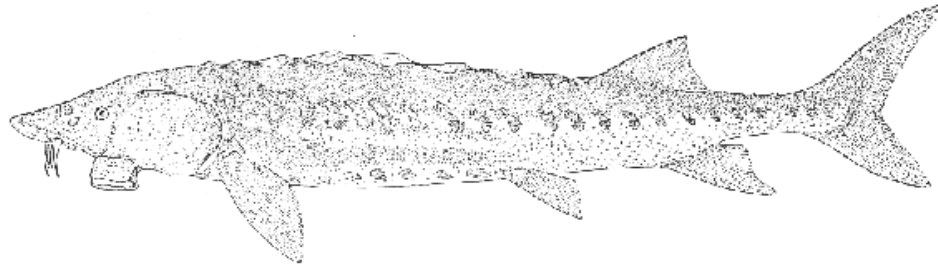


**PETITION TO LIST THE NORTH AMERICAN
GREEN STURGEON (*Acipenser medirostris*)
AS AN ENDANGERED OR THREATENED SPECIES
UNDER THE ENDANGERED SPECIES ACT**



**ENVIRONMENTAL PROTECTION INFORMATION CENTER
CENTER FOR BIOLOGICAL DIVERSITY
WATERKEEPERS NORTHERN CALIFORNIA
PETITIONERS
JUNE 2001**

NOTICE OF PETITION

Environmental Protection Information Center
P.O. Box 397
Garberville, CA 95542
(707) 923-2931
Contact: Cynthia Elkins

Center for Biological Diversity
P.O. Box 40090
Berkeley, CA 94704
(510) 841-0812
Contact: Jeff Miller

WaterKeepers Northern California
Presidio Building 1004
San Francisco, CA 94129
(415) 561.2299 ext. 14
Contact: Jonathan Kaplan

Petitioners Environmental Protection Information Center (“EPIC”), Center for Biological Diversity (“CBD”), and WaterKeepers Northern California (“WaterKeepers”) formally request that the National Marine Fisheries Service (“NMFS”) list the North American green sturgeon (*Acipenser medirostris*) as an endangered species under the federal Endangered Species Act (“ESA”), 16 U.S.C. §§ 1531-1544. In the alternative, petitioners formally request that NMFS list the North American green sturgeon as a threatened species under the ESA. In either case, petitioners request that green sturgeon critical habitat be designated concurrent with the listing designation. This petition is filed under §553(e) of the Administrative Procedure Act (“APA” - 5 U.S.C. §§ 551-559), §1533(b)(3) of the ESA, and 50 C.F.R. §424.14(b). This petition sets in motion a specific administrative process as defined by §1533(b)(3) and 50 C.F.R. §424.14(b), placing mandatory response requirements on NMFS.

Because *A. medirostris* is an anadromous fish, NMFS has jurisdiction over this petition. A Memorandum of Understanding (“MOU”) between NMFS and the U. S. Fish and Wildlife Service (“USFWS”) signed in 1974, regarding jurisdiction over endangered and threatened species, clearly places jurisdictional responsibilities for the green sturgeon with NMFS (NMFS and USFWS 1974). The MOU states that NMFS has jurisdiction over all non-mammalian species (other than members of the classes Aves, Amphibia, and Reptilia) “which either (i) reside the major portion of their lifetimes in marine waters; or (ii) are species which spend part of their lifetimes in estuarine waters, if the major portion of the remaining time (the time which is not spent in estuarine waters) is spent in marine waters.” The green sturgeon meets both of these criteria. According to the current USFWS web site: “Generally, the National Marine Fisheries deals with those species occurring in marine environments and anadromous fish, while the Fish and Wildlife Service is responsible for terrestrial and freshwater species and migratory birds.”

EPIC is a community-based, nonprofit organization that actively works to protect and restore native plants and animals, watersheds, and natural ecosystems in the redwood region of California. EPIC pursues an integrated approach toward this mission that includes research, education, advocacy, and legal defense of the environment.

CBD is a nonprofit environmental organization dedicated to the protection of native species and their habitats in the Western Hemisphere. CBD works to protect and restore natural ecosystems and

imperiled species through science, education, policy, and environmental law.

WaterKeepers is a non-profit organization whose mission is to protect, preserve, and enhance the resources and health of the ecosystems and communities of the San Francisco Bay and Delta region. To accomplish its mission, WaterKeepers employs a unique combination of on-the-water citizen patrols, water quality monitoring, regulatory oversight, Clean Water Act enforcement, and environmental education.

EPIC, CBD, and WaterKeepers submit this petition on their own behalf and on behalf of their members and staff, with an interest in protecting the green sturgeon and the sturgeon's habitat.

EXECUTIVE SUMMARY

The Environmental Protection Information Center, the Center for Biological Diversity, and WaterKeepers Northern California are formally requesting that the National Marine Fisheries Service list the green sturgeon (*Acipenser medirostris*) as endangered or threatened under the federal Endangered Species Act. These organizations also request that critical habitat for the green sturgeon be designated concurrent with its listing. The petitioners are conservation organizations with an interest in protecting the green sturgeon and all of earth's remaining biodiversity.

The North American green sturgeon is a large anadromous fish that ranges from Alaska to Mexico in marine waters, feeds in estuaries and bays from San Francisco Bay to British Columbia, and spawns in fresh water in the mainstem of only a handful of large rivers. The remaining green sturgeon populations exist in rivers that have been extensively dammed, diverted, and polluted. Sturgeons in general are highly vulnerable to habitat alteration and over-fishing because of their specialized habitat requirements, the long time it takes them to reach breeding maturity, and their episodic reproductive success. The large size and sluggish nature of sturgeons make them easy to net and snag.

Recent genetic studies show that the Asian forms (including the "Sakhalin sturgeon" of Russia) of the green sturgeon can be considered a separate species (*Acipenser mikadoi*) from the North American green sturgeon. Regardless of taxonomy, the green sturgeon appears to be in trouble throughout its range. It is apparently extinct in Japan, endangered in Russia, and has been given "rare" status in Canada. The information presented in this petition shows that the North American green sturgeon has a high risk of extinction.

The only remaining spawning populations of North American green sturgeon are in the Sacramento and Klamath River basins in California and possibly in the Rogue River in Oregon. These rivers all have flow regimes affected by water projects, limiting suitable spawning conditions for green sturgeon. Increasing urban and agricultural demand for water from these rivers potentially threatens the future spawning success for the entire species. The southernmost green sturgeon populations occur in California, a region experiencing dramatic declines of its anadromous fishes due to dams, water withdrawals, and habitat alteration. A number of presumed spawning populations of green sturgeon have been lost since the 1960s and 1970s (in the Eel River, South Fork Trinity River, and San Joaquin River). Severe declines of green sturgeon have been noted recently in northern rivers which may have once had spawning populations, such as the Umpqua River in Oregon and the Fraser River in Canada.

The history of sturgeon fisheries throughout the world has been one of overexploitation followed by severe population reduction. Although there is not much historic data on green sturgeon, early accounts from fishermen and the well-documented collapse of the Columbia River white sturgeon fishery due to over-fishing indicate that green sturgeon stocks were likely severely depleted before the turn of the century. Further declines in abundance were noted in the mid-20th century due to continued over-harvest and habitat destruction.

Although more restrictive size limit restrictions have been gradually implemented, present fisheries probably continue to deplete a stock of large, old fish that cannot renew itself at present harvest rates. Until recently, various west coast fisheries were harvesting at least 6,000 to 11,000 green sturgeon per year. In recent years, these fisheries have been harvesting a conservatively estimated minimum of 3,000 to 5,000 green sturgeon annually. Although statistics are incomplete, it is likely that fishing pressure has been increasing as Pacific salmon and white sturgeon stocks decline. Of particular concern are commercial fisheries in the Columbia River and Washington coastal region, and the developing tribal gill net fishery on the Klamath River, which targets the largest known spawning population of green sturgeon.

The principal fisheries for green sturgeon are in south coastal Washington and in the nearby Columbia River estuary, yet there is no evidence of sturgeon spawning in that region. These fisheries may depend on sturgeon from California that are attracted to the area for abundant food resources. Recent

Oregon and Washington trawl catch statistics show evidence of continued green sturgeon decline. There has been a dramatic decline of trawl by-catch of green sturgeon off Vancouver Island and in the salmon net fishery in the lower Fraser River in Canada. The trawl catches are good indexes of abundance since green sturgeon are not targeted by these fisheries, but are taken incidentally.

It is currently estimated that each of the three known or suspected spawning populations of green sturgeon probably contain a few hundred mature females, at best (Musick et al. 2000). This is cause for alarm, because with so few females of reproductive age, not only do fish have a hard time finding each other for spawning, but also maintaining minimum population sizes for genetic diversity becomes a concern. Green sturgeon are particularly at risk because their ecology and population structure are so poorly studied and understood.

A 1992 NMFS status review of the species in California (Moyle et al. 1992) made a “conservative” recommendation that the green sturgeon be regarded as a threatened species. The American Fisheries Society (Musick et al. 2000) recently reviewed the risk of extinction for marine fish in North American waters and determined that the green sturgeon is endangered, noting an 88% decline in most of its range. The green sturgeon clearly warrants prompt listing as an endangered or threatened species under the Endangered Species Act.

TABLE OF CONTENTS

Notice of Petition.....	i
Executive Summary.....	iii
Table of Contents.....	v

I. NATURAL HISTORY AND STATUS OF THE GREEN STURGEON.....1

A. NATURAL HISTORY 1

1. Description	1
2. Taxonomy.....	2
3. Distribution	4
4. Habitat	5
5. Behavior	6
a. Movement	6
b. Reproduction and Growth.....	7
c. Feeding	9
6. Natural Mortality	10
a. Predators	10
b. Disease	10

B. DISTRIBUTION AND ABUNDANCE 11

1. California	11
a. Southern California	11
b. San Francisco Bay System	12
i. S. F. Bay & Sacramento-San Joaquin Delta	13
ii. Sacramento River	14
iii. San Joaquin River	15
c. North Coast	15
i. Eel River	16
ii. Humboldt County	17
iii. Klamath-Trinity River System	18
iv. Del Norte County	21
2. Oregon	21
a. South Coast Bays & Estuaries	22
b. Rogue River	22
c. Coos Bay	23
d. Umpqua River/Winchester Bay	23
e. Middle Coast Bays & Estuaries	25
f. North Coast Bays & Estuaries	26
g. Columbia River System	27
3. Washington.....	28
a. Willapa Bay	28
b. Grays Harbor	28
c. Puget Sound	29
4. Canada.....	29
5. Alaska	31
6. Russia and Asia	31
a. Russia	32
b. Japan	33
c. Korea	33
d. China & Taiwan	34

II.	CRITERIA FOR ENDANGERED SPECIES ACT LISTING	35
A.	THE GREEN STURGEON IS A “SPECIES” UNDER THE ESA	35
B.	THE GREEN STURGEON IS ENDANGERED OR THREATENED UNDER THE ESA	35
1.	Present or Threatened Destruction, Modification, or Curtailment of Its Habitat or Range	36
2.	Overutilization for Commercial, Recreational, Scientific, or Educational Purposes	39
a.	Fisheries	39
i.	San Francisco Bay System	41
ii.	Klamath-Trinity River System	42
iii.	Oregon Coastal Areas	43
iv.	Columbia River	43
v.	Washington Coastal Areas	44
vi.	Ocean Trawl Fisheries	45
vii.	Canadian Fisheries	46
3.	Disease and Predation	46
4.	Inadequacy of Existing Regulatory Mechanisms	47
5.	Other Natural or Anthropogenic Factors	50
a.	Entrainment	50
b.	Toxic Substances	51
III.	CONCLUSION	53
IV.	CRITICAL HABITAT	54
V.	SIGNATURE PAGE	55
VI.	APPENDICES	56
	Appendix 1 - California and Coastal Oregon Green Sturgeon Sport Catch	56
	Appendix 2 - Klamath River Green Sturgeon Catch	57
	Appendix 3 - Lower Columbia River Green Sturgeon Catch	58
	Appendix 4 - Grays Harbor and Willapa Bay Green Sturgeon Catch	60
	Appendix 5 - Washington and Oregon Green Sturgeon Trawl Catch	62
	Appendix 6 - Overall Green Sturgeon Catches	63
VII.	BIBLIOGRAPHY OF LITERATURE CITED	65

I. NATURAL HISTORY AND STATUS OF THE GREEN STURGEON

A. NATURAL HISTORY

The green sturgeon¹ is the most widely distributed and the most marine-oriented fish of the sturgeon family. Green sturgeon are one of only three species of saltwater sturgeon in the world and the most marine sturgeon in the Pacific. White sturgeon reside in many of the bays where green sturgeon are found, but are primarily an estuarine species. Green sturgeon are believed to spend most of their lives in ocean waters, moving into estuaries and bays to feed and into freshwater mainly to spawn. The early life stages in fresh water may last as long as four years. Anadromous² species of sturgeon, such as the green sturgeon, are the largest fish found in fresh water.

The biology and population trends of the North American green sturgeon (*Acipenser medirostris*) remain poorly understood, and much of its behavior and habitat requirements are inferred from studies of white sturgeon (*A. transmontanus*). Although the two species share a somewhat overlapping range in North America, green sturgeon adults are more marine than white sturgeon, spending limited time in estuaries or fresh water. The ecology of green sturgeon has received comparatively little study because of their generally low abundance, limited spawning distribution, and low commercial and sportfishing value relative to white sturgeon.

1. Description

Sturgeons are often said to resemble some sort of prehistoric creature, due to their large size, shark-like tails, and armored covering of bony plates. Sturgeons are indeed unusual looking fish, possessing a skeleton that is more cartilage than bone; heavy, sandpaper-like skin; and rows of bony plates (called scutes) for protection rather than scales. Underneath their flattened snouts are sensory barbels and a toothless “vacuum cleaner” mouth capable of siphoning up food.

Green sturgeon are generally olive green in color, with an olivaceous stripe down each side and scutes that are paler than the body.³ Adult green sturgeon have long, narrow, “shovel-like” snouts, with four barbels in a transverse row on the underside. The barbels are closer to the mouth than the tip of the snout (the barbels are closer to the snout on white sturgeon). Their mouths have highly protrusible lips but lack teeth.

Each fish has five widely separated rows of bony scutes on the body. The dorsal row of scutes numbers 8 to 11, the two lateral rows have 23 to 30 scutes each, and the two bottom rows have 7 to 10 scutes each. Green sturgeon also have one large scute behind the dorsal fin as well as one behind the anal fin (both lacking in white sturgeon). The scutes of green sturgeon tend to be sharper and more pointed than those of white sturgeon. The dorsal fin on green sturgeon has 33 to 36 rays and the anal fin has 22 to 28 rays. Young of year green sturgeon can be distinguished from white sturgeon by their lesser number of rays on the dorsal fin (33 to 36 for greenies while white sturgeon have 42 or more) and their 30 or fewer lateral scutes (white sturgeon have more than 35) (Moyle et al. 1992).⁴ The position of the anal vent in

¹ “Green sturgeon” refers to both the North American and Asian forms of green sturgeon.

² Anadromous = ascending rivers from the ocean for breeding.

Some green sturgeon have been reported to be grayish-white. There have also been reports and specimens of “golden sturgeon,” from brown to gold in color, from the Sacramento and Rogue Rivers. These golden sturgeon, which may be a second morphotype of *A. medirostris*, are briefly discussed in the section on taxonomy.

The recorded meristic characters of green sturgeon differ somewhat throughout the literature (Snyder 1908; Schreiber 1960; Miller and Lea 1972; Bond 1973; Fry 1973; Hart 1973; Scott and Crossman 1973; Wydoski and Whitney 1979; Wang 1986; Artyukhin and Andronov 1990), but the defining characters noted by Moyle et al. (1992) have generally been used in recent literature. However, recent sampling of

relation to the base of its ventral fins has been the main characteristic used in Washington to tell the two sturgeon species apart (S. Wright, pers. comm., 2001).

Adult green sturgeon can reach sizes of 2.3 meters (m) in length (7 _ feet) and 159 kilograms (kg) in weight (350 pounds), but they seldom exceed 2 m (6 _ feet) and 90 kg (198 pounds) (Skinner 1982).

2. Taxonomy

Sturgeon are modern relicts of the ancient group of bony fishes, having remained relatively unchanged from when they first appeared 200 million years ago. Taxonomically, they belong to the infraclass *Chondrostei*, along with paddlefishes, numerous fossil fishes, and the ancestors of all other bony fishes. Sturgeons themselves are not ancestral to modern bony fishes but are a highly specialized and successful offshoot of the ancestral chondrosteans, retaining ancestral features such as a heterocercal tail⁵, similar fin and jaw structure, and spiracle (breathing orifice).

The green sturgeon was described as *Acipenser medirostris* in 1854 by W. O. Ayres, the only one of three sturgeon species he described from San Francisco Bay that is still recognized. The name *Acipenser* is Latin for sturgeon. Ayres (1854) described three “species” of sturgeon caught in San Francisco Bay, differentiated in part by the length of their snouts and accordingly named *A. Acutirostris*, *A. medirostris*, and *A. brachyrhynchus*. The long (“sharp”) and short snouted forms were later determined to be white sturgeon, leaving the green sturgeon with an anomalous species name that translates as “middle snout.” At least the common name is apt, because green sturgeon often have a distinct green cast to their appearance.

While there is no question about the validity of *A. medirostris* as a species, geographic variation has received little attention until recently. Although Russian and Asian forms of the green sturgeon are morphologically similar to the North American form and even share some unusual parasites (P. Foley, University of California, Davis, pers. comm., as cited in Moyle et al. 1992), they likely belong to different taxon. The history of the nomenclature and species status of the green sturgeon of North America and the ‘Sakhalin sturgeon’ of the northeastern Pacific in Russia and Asia has been particularly confusing.

Nearly forty years after Ayres described the North American green sturgeon, Hilgendorf (1892) described an Asian sturgeon species caught in the northern waters of Japan as *A. mikadoi*. Schmidt (1904) subsequently referred to a sturgeon caught in the Aniwa Bay of Sakhalin Island as *A. mikadoi*. However, Jordan and Snyder (1908) cautioned that the Japanese population was described as *A. mikadoi* based on one poorly preserved specimen. Berg (1911, 1948) considered the Sakhalin sturgeon to be conspecific with the North American green sturgeon, *A. medirostris*. Schmidt (1950) eventually reconsidered his 1904 view, and designated the Sakhalin sturgeon as a subspecies of *A. medirostris*, *A. medirostris mikadoi*. Three scientific names have thus coexisted in the literature for the Asian and Russian forms of green sturgeon.

Recent DNA measurements indicate that the Asian form has about twice the DNA content of the North American green sturgeon (Birstein 1993), and molecular analyses indicate the two populations are distinct (Birstein et al. 1997). Birstein (1993) and Birstein et al. (1993) suggested they are two different species - *A. mikadoi* Hilgendorf, 1892 and *A. medirostris* Ayres, 1854. This designation is bolstered by molecular data on three mitochondrial genes presented by Birstein and DeSalle (1998) that also shows significant differences between these two species. Other recent molecular data shows a close genetic relationship between *A. medirostris* and *A. transmontanus* (Brown et al. 1996; Birstein et al. 1997).

meristic characters from 50 Columbia River green sturgeon by ODFW (2000) turned up slightly different results. Dorsal scutes numbered 7 to 12, lateral scutes 22 to 33, ventral scutes 7 to 12; dorsal fin rays numbered 12 to 36, anal fin rays 11 to 19. Differences in meristic characters may reflect sampling of different stocks or forms of green sturgeon.

Heterocercal = the upper tail lobe larger than the lower with the end of the vertebral column prolonged and somewhat upturned in the upper lobe.

Therefore, *A. mikadoi* and *A. medirostris* should be considered as morphologically similar, but genetically different, species.

For the purposes of this petition, *A. medirostris* refers to the North American green sturgeon, but “green sturgeon” refers to both the North American and Asian forms unless otherwise specified. The distribution, abundance, and known status of the Asian form, *A. mikadoi*, is discussed in the section on distribution and abundance below.

The stock structure of *A. medirostris* is currently unknown. There may prove to be distinct genetic stocks (populations) of North American green sturgeon, rather than one common gene pool. Attempts are underway to comprehensively study North American green sturgeon genetics, using standard protein electrophoretic techniques and mitochondrial DNA analysis (Mulligan et al. 1996). Defining potentially distinct Pacific Coast populations is absolutely essential for management of green sturgeon - for example it is currently unknown whether green sturgeon are utilizing multiple natal streams. Without knowledge of stock structure, it cannot be determined whether fisheries in Oregon and Washington are harvesting green sturgeon derived from California populations at rates that are not sustainable.

Reports and specimens of “golden sturgeon” from the Sacramento River indicate there may be a second morphotype of *A. medirostris* that is not currently recognized. There have been anecdotal reports and at least one newspaper photo of golden sturgeon (with a clear ventral stripe) caught by sport fishers in the San Francisco Bay system (CDFG 1999). Five wild sturgeon (identified as green sturgeon) larvae taken from the Sacramento River in 1994 were noted to be brown to golden in color. The fish lacked ventral pigmentation, but most had brown ventrolateral stripes. These sturgeon were taken with ten other larvae positively identified as green sturgeon based on meristic counts, anatomy, and pigmentation patterns, and none of the five were thought to be white sturgeon (Foley 1994). Sturgeon fishers on the Rogue River have also reported two color versions of green sturgeon - brown/tan/beige fish and green fish. The brown version is reportedly fatter and seen upriver in the spring, whereas the green version arrives upriver later in the year (ODFW 2000).

3. Distribution

Green sturgeon are found on both sides of the Pacific, having been recorded from the coasts of Mexico, the United States, Canada, Russia, Japan, Korea, China, and Taiwan. They are rarely found below the 30th parallel and their greatest abundance occurs between the 40th and 60th parallels.

The Asian records should be regarded as those of the closely related Sakhalin sturgeon, *A. mikadoi*. In Asia, green sturgeon have been found from the Bering Sea in the north down to the Sea of Japan and the southwest coast of Korea in the south (Morrow 1980; Borodin et al. 1984). Green sturgeon have been most abundant in Asia in the region of the Tatar Strait, between Sakhalin Island and the Russian Coast. Their principal spawning stream seems to be the Tumnin (Datta) River in Russia. The historic and current distribution of *A. mikadoi* is discussed more thoroughly below.

The North American green sturgeon, *A. medirostris*, ranges in the ocean from the Bering Sea, Alaska, to occasionally as far south as Ensenada, Mexico. The species frequents numerous estuaries and bays from British Columbia, Canada, south to Monterey Bay, California. Green sturgeon have been found in river mouths from the Skeena River, British Columbia, south to the Sacramento River, California. However, they are only found significant distances inland in fresh water in a handful of rivers in Oregon and California. The only suspected or confirmed remaining spawning runs of green sturgeon occur in the Rogue River, Oregon, and the Klamath and Sacramento river systems in California, with fish sometimes traveling more than 150 km (93 miles) upstream to spawn.

There is no evidence of green sturgeon spawning in Alaska or Canada, although specimens have been reported from unknown distances up the Taku River (McPhail and Lindsey 1970) and the Copper

River (Evermann and Goldsborough 1907a, b) in Alaska, and in the estuaries of the Skeena and Fraser Rivers in Canada (Scott and Crossman 1973; Houston 1988; Glavin 1996).

Green sturgeon are relatively abundant in the Columbia River estuary and fish historically were observed 225 km (140 miles) up the Columbia River before the construction of large dams (ODFW 1991). Green sturgeon are now found almost exclusively in the lower 60 km (37 miles) of the Columbia and do not occur upstream of Bonneville Dam (ODFW 1991). There is no evidence of spawning in the Columbia or any other rivers in Washington. In Oregon, green sturgeon are found in many coastal estuaries and juvenile green sturgeon have been found in several of the coastal rivers (Emmett et al. 1991), but small juveniles have only been found in the Rogue River (A. Smith, ODFW, unpublished observations).

In California, green sturgeon have been collected in small numbers in marine waters from the Oregon border to the Mexican border. Marine abundance of the species gradually increases northward of Point Conception. Adult fish have been observed in a handful of rivers, but spawning populations are known only in the Sacramento and Klamath river systems. Additional spawning populations apparently once existed in the Eel River and in the South Fork Trinity River, and also possibly in the San Joaquin River. The Klamath and Trinity rivers remain the principal spawning streams in California. The distribution of *A. medirostris* is discussed more thoroughly in the section on distribution and abundance below.

4. Habitat

Green sturgeon are a demersal (bottom dwelling) species, mostly seen from inshore waters to 60 m (197 feet). Adults are anadromous and reside in subtidal areas. They are most often observed in the seawater and mixing zones of bays and estuaries, where they feed, and are occasionally found in the lower stretches of some rivers. In estuaries, sturgeon tend to concentrate in deep areas with soft bottoms, although they commonly move into intertidal areas to feed at high tides. Adults and juveniles have been found primarily on clean sand in rivers (Emmett et al. 1991).

Green sturgeon spawn in the mainstem of large river systems in relatively fast water flows and probably in depths greater than three meters (Emmett et al. 1991). Adult green sturgeon have historically been seen and caught in deep holes in rivers during spawning season. The preferred spawning substrate likely is large cobble, but can range from clean sand to bedrock. The importance of water quality is uncertain, but silt is known to prevent the eggs from adhering to each other (Moyle et al. 1994; Conte et al. 1998).

Free-flowing rivers and seasonal floods provide suitable spawning conditions for green sturgeon. Flowing water provides oxygen, disperses eggs, and may impede egg predators. Seasonal floods scour substrates free of sand and silt which might suffocate the eggs. Seasonal floods and corresponding changes in temperature, velocity, and turbidity are presumed to provide spawning cues for white sturgeon (Kohlhorst et al. 1991). The habitat requirements of green sturgeon are poorly studied, but their spawning and larval ecology are probably similar to that of white sturgeon. The comparatively large size of their eggs, thin corionic layer on the egg, and other characteristics indicate that green sturgeon probably require colder, cleaner water for spawning than white sturgeon (S. Doroshov, University of California, Davis, pers. comm., as cited in USFWS 1995).

Green sturgeon larvae likely inhabit similar benthic freshwater areas as white sturgeon larvae (Stevens and Miller 1970). Production of young white sturgeon in the Sacramento River system has been associated with freshwater outflow - in years with very high outflow during spring and early summer, more young of year sturgeon have been produced. High flows are thought to improve young sturgeon survival by transporting larvae to areas of greater food abundance, by dispersing larvae over a wide area of rivers and estuaries to take advantage of all available habitat, by quickly moving larvae downstream of any influence of water diversions in the Delta, or by enhancing productivity in the nursery area by increasing the nutrient supply. Additionally, adults may experience a stronger attraction to upstream spawning areas in high flow years and spawn in greater numbers. (CDFG 1992).

Juveniles may occur in shallow water (Radtko 1966) and probably move to deeper and more saline areas as they grow. In estuaries, off-channel, slow-water habitats have favored the capture by seining of juvenile green sturgeon (Nakamoto et al. 1995).

Because of the unique features of their large river habitats and adaptive life history characteristics, green sturgeon require a much broader definition of habitat than is typically applied to fish. Fish habitats are often defined in terms of site-specific conditions such as depth, velocity, substrate, and cover. Sturgeon habitat must be defined in terms of system-wide conditions including large areas of diverse habitat; natural variation in flow, velocity, temperature, and turbidity; high water quality; a broad prey base; and free-flowing sections which provide suitable spawning sites.

5. Behavior

a. Movement

Green sturgeon are highly migratory fish, with both juveniles and adults apparently moving extensively up and down the coast. Individual fish range widely, presumably to take advantage of scattered and seasonally abundant food resources. Regular migrations for spawning and short-term movements for feeding have been observed. Long distance movements are facilitated by the large size, shape, and swimming ability of green sturgeon, which allow them to move through strong current.

Individual fish tagged by the California Department of Fish and Game ("CDFG") in the Sacramento-San Joaquin estuary have been recaptured off Santa Cruz, California; in Winchester Bay on the southern Oregon coast; at the mouth of the Columbia River; and in Gray's Harbor, Washington (Chadwick 1959; Skinner 1962; Miller 1972b). Most tags for green sturgeon tagged in the San Francisco Bay system have been returned from outside that estuary, but no fish tagged in Oregon or Washington have been returned in California.⁶ Limited tagging and recapture was done of 25 green sturgeon in the Klamath and Trinity Rivers from 1992 to 1997. All recaptures were made within the Klamath-Trinity basin, with fish moving up to 27 miles within the system (HVTC-FD 1997).

Adult green sturgeon move from the ocean to estuaries and the lower reaches of rivers between late winter and early summer. Mature adults ascend rivers to spawn in the spring and early summer. Adult immigration to the Klamath River occurs between late February and late July - the spawning period being March through July, with a peak from mid-April to mid-June (CH2M Hill 1985; Emmett et al. 1991). Spawning times in the Sacramento River are thought to be similar (Emmett et al. 1991; USFWS 1995). Adult green sturgeon are presumed to leave rivers shortly after spawning, with adults appearing to migrate back to the ocean during summer and fall (Emmett et al. 1991). Adult green sturgeon have also been found in freshwater short distances up rivers where there is no known spawning.⁷

Not much is known about the movement of larval green sturgeon. It is known that movement and dispersal of white sturgeon in the Sacramento River system is dependent upon river flows. In high flow years, many white sturgeon larvae are found in the Delta and upper bays, but in dry years most larvae remain in the rivers (Stevens and Miller 1970). The location of the nursery area for most young of year fish appears to move farther downstream as flows increase (Kohlhorst 1976).

Juveniles seem to migrate out to sea when they are one to four years of age (although many leave as yearlings), primarily during summer through fall (Emmett et al. 1991). Juvenile green sturgeon (most from 30 to 70 cm in length) emigrate from the Klamath River from late May through July; on the Trinity River emigration runs from early June through early September (CH2M Hill 1985; USFWS 1999). Juveniles appear to inhabit estuarine environments for four to six years before migrating to the ocean (CDFG 1992;

Only small numbers of green sturgeon have been tagged in Washington and Oregon. Tagging studies can be inconclusive, since many fishermen do not return tags and some types of tags have high shedding rates.

⁷

Up to 55 km inland in the Smith River during December and 60 km inland in the Columbia River, with no evidence of spawning in either river.

USFWS 1999), moving out to near shore waters and migrating considerable distances as they grow larger (Emmett et al. 1991).

Coastal migratory behavior is quite common for immature green sturgeon. The continental shelf as well as most coastal bays and estuaries throughout the Pacific Northwest appear to serve as habitat for individuals during this portion of their life history (Roedel 1941; Norris 1957; Miller 1972; USFWS 1981, 1982). It is therefore unknown what portion of immature fish in a lower river and estuary are from a local spawning population. The presence of adults upstream, or juveniles or sexually immature green sturgeon in lower river reaches is not evidence of a spawning population in a river system.

Numerous sexually immature green sturgeon have been encountered in the lower 6 km of the Klamath River, but a conspicuous lack of sturgeon between 70 and 120 cm has been observed during sampling (USFWS 1992; Nakamoto et al. 1995). Green sturgeon reach sexual maturity at a minimum of 130 to 140 cm of length. This suggests that as juveniles approach sexual maturity, they increasingly avoid the riverine environment until they are ready to enter the spawning population.

b. Reproduction and Growth

Green sturgeon spawn in the mainstem of large river systems during late spring and early summer, in relatively fast water flows (Emmett et al. 1991). Adult green sturgeon have historically been seen and caught in deep holes in rivers during spawning season. White sturgeon are known to require water depths of greater than nine feet (Galbreath 1979) and water temperatures of approximately 10° C (Kohlhorst 1976) for spawning. Adult sturgeon are seen in the Sacramento River, presumably spawning, when temperatures range from 8° to 14° C.

The preferred spawning substrate likely is large cobble, but can range from clean sand to bedrock. Females are oviparous,⁸ broadcast-spawning eggs that are fertilized externally. After spawning, the adhesive eggs of sturgeon settle to the river bottom and attach to substrates, most likely cobblestones. The importance of water quality is uncertain, but silt is known to prevent the eggs from adhering to each other and excessive fine sediment can prevent their attachment on the bottom following spawning (Moyle et al. 1994; Conte et al. 1998).

The fecundity of ripe female green sturgeon sampled in the Klamath River in 1981 averaged 127,500 eggs, with a range from 51,000 to 224,000 eggs per fish (USFWS 1982). Female green sturgeon in Siberia are known to produce from 60,000 to 140,000 eggs, which are about 3.8 millimeters (mm) in diameter. Fecundity is presumed to increase with the age and size of the female - ripe white sturgeon from the Sacramento River produced numbers of eggs ranging from 100,000 eggs in a 49-inch fish to 190,000 in a 65-inch fish (unpublished data, as cited in Skinner 1972).

Based on their presumed similarity to white sturgeon, green sturgeon eggs probably hatch around 196 hours (at 12.7° C) after spawning, and the larvae should be 8 to 19 mm (0.3 to 0.7 inch) long (Kohlhorst 1976). Larvae of Russian green sturgeon are about 12.3 mm long at hatching (Artyukhin and Andronov 1990).

The fresh water rearing requirements for juvenile green sturgeon are generally unknown. Successful recruitment of white sturgeon has been highly correlated with spring and summer discharge (Stevens and Miller 1970; Kohlhorst et al. 1991). Juvenile green sturgeon are thought to remain within fresh water environments from one to four years before emigrating to the estuary.⁹ Juveniles apparently remain near estuaries at first, but migrate considerable distances as they grow larger (Emmett et al. 1991). Moyle et

⁸ Oviparous = producing eggs which hatch after leaving the body of the female.

In the Klamath River, most juvenile sturgeon out migrate at 30-70 centimeters (cm) total length (12-28 inches), when they are one to four years old, although many leave as yearlings (USFWS 1982; USFWS 1995; Nakamoto et al. 1995).

al. (1995) presumed that juvenile green sturgeon leave the estuary to migrate to the ocean before they are two years of age, although they possibly inhabit estuarine environments for up to four to six years (CDFG 1992; USFWS 2000).

Male and female green sturgeon grow at about the same rates: approximately 7 cm (3 inches) per year until they reach maturity at 130-150 cm total length (TL) (51 to 59 inches), around age 15-20, after which growth slows down (USFWS 1982; Nakamoto et al. 1995). Thus a 10 year old sturgeon is about 105 cm TL (about 41 inches), a 20 year old about 160 cm TL (63 inches), a 30 year old about 195 cm TL (77 inches), and a 40 year old about 200 cm TL (79 inches). Males mature at younger ages than females and so do not grow as large. The largest green sturgeon are typically females and virtually all fish more than 200 cm (79 inches) long are female (USFWS 1982).

Adult green sturgeon can reach sizes of 2.3 m (7 _ feet) and 159 kg (350 pounds), but they seldom exceed 2 m (6 _ feet) and 90 kg (198 pounds) (Skinner 1982). The largest fish have been aged at 42 years (Nakamoto et al. 1995), but this is probably a considerable underestimate (USFWS 1982) and ages of 60 to 70 years or more are likely (Emmett et al. 1991). White sturgeon have reportedly been known to reach an estimated age of 100 years (CDFG 1992). The largest green sturgeon recorded in recent years from the Klamath River was about 230 cm TL (91 inches) (USFWS 1982). In California green sturgeon seldom exceed 1.3 m fork length (FL) (about 51 inches) and 45 kg (about 100 pounds) (Skinner 1962).

Green sturgeon life history can be divided into three general phases: freshwater juveniles (less than three years old); coastal migrants (three to thirteen years old for females and three to nine years old for males); and adults (greater than thirteen years old for females and greater than nine years old for males). Fish between 70 and 120 cm TL are apparently entirely marine, so males are spending three to nine years at sea, and females three to thirteen years.

Analysis of fin rays from fish collected in the Klamath River from 1990 to 1993 suggests that male green sturgeon become sexually mature sometime after reaching 120 cm TL while females mature after attaining 145 cm TL (Nakamoto et al. 1995). Spawning fish in the Klamath River were aged using 122 fin rays collected from 1979 to 1982. Spawner ages ranged from 15 to 40 years, with females averaging 28 years old, and males 21 years (USFWS 1983). Sturgeon aged from 148 fin rays collected from 1990 to 1993 found spawning females to average 32 years old and males 23 years (Nakamoto et al. 1995). Female green sturgeon may return to spawn every three to seven years (CDFG 2000). Female white sturgeon are thought to spawn as infrequently as every five years, with males spawning more frequently (CDFG 1992).

An alternative method for determining the age of green sturgeon is taking cross-sections of fin rays or spines and counting the number of visible rings, on the assumption that a new ring is laid down every year¹⁰ (Kohlhorst et al. 1980; Brennan and Cailliet 1991). The length to age relationship worked out above for green sturgeon correlates closely to counting fin ray growth rings (Nakamoto et al. 1995), but there can be significant difficulties in aging fin ray sections since the annular patterns in cross sections are sometimes extremely difficult to differentiate. Pectoral fin rays of sturgeon have been the easiest to analyze and provide the most precise age measurements, yet visible depositional patterns are not always apparent in laboratory grown sturgeons, possibly due to temperature, salinity, and diet differences from wild sturgeon (Kohlhorst et al. 1980; Brennan and Cailliet 1991). Additional factors such as reduced growth rates of older and pre-spawning age fish, formation of spawning checks, long migrations, or adverse environmental conditions may make it more difficult to accurately assess age from fin ray sections (Nakamoto et al. 1995).

c. Feeding

Sturgeons are opportunistic predators that eat a variety of prey and switch foods as prey availability

The annular patterns consist of alternating dark and translucent bands - the wide dark bands resulting from abundant formation of connective tissue during the summer and the narrow translucent bands corresponding to metabolic inactivity during the winter (Brennan and Cailliet 1991).

changes (Turner 1966). Sturgeon generally feed on invertebrates in the benthic food chain where most production occurs in large river systems (Sheehan and Rasmussen 1993). However, occasional pursuit and capture of active prey contradicts the image of sturgeons as merely sluggish bottom scavengers (Beamesderfer and Farr 1997).

Green sturgeon are primarily bottom feeders, highly adapted for preying on benthic animals, which they detect with a row of extremely sensitive barbels on the underside of their snouts. The mouth is ventrally located and sturgeon move along the bottom sucking up mud and debris, sifting out the organisms on which they feed. Green sturgeons protrude their extraordinarily long and flexible “lips” to suck up their food (Moyle et al. 1995). Sturgeons have a spiral valve intestine that aids in food absorption.

The stomach contents of green sturgeon have been recorded from various trawl surveys. The known foods of green sturgeon are primarily shrimp, crabs, worms, amphipods, and isopods. Large sturgeon will eat fish, but their piscivorous diet consists primarily of fish that are small, disabled, or dead (Fitch and Lavenberg 1971).

Green sturgeon larvae initially feed on their yolk sac (Emmett et al. 1991). The location of green sturgeon larvae caught during a survey in the San Francisco Bay Delta (33 of 34 larvae were caught during 16 bottom sets, and only one larvae was caught in 8 surface and midwater sets) seems to provide evidence that *A. medirostris* larvae are also primarily bottom feeders (Stevens and Miller 1970).

Young green sturgeon caught in the San Francisco Bay Delta fed almost exclusively on crustaceans (amphipods, mysids, and other shrimp-like creatures). Juveniles in the Sacramento-San Joaquin Estuary are known to feed on opossum shrimp, *Neomysis mercedis*, and amphipods, *Corophium* spp. (Radtke 1966). Juveniles trawled in San Pablo and Suisun Bays had consumed a variety of foods, including *Corophium* spp., annelid worms (*Crago franciscorum*), opossum shrimp (*Neomysis awatchensis*), *Macoma* spp., the amphipod *Photis californica*, the isopod *Synidotea laticauda*, unidentified crab, and fish (Ganssle 1966). Trawls of the Delta by Turner (1966) revealed *Corophium* to be most important food item of smaller green sturgeon, and the only food item found in their stomachs in the fall. In spring and summer, *Corophium* made up over half of juvenile sturgeons’ diet, with *N. awatchensis* also heavily utilized (Turner 1966).

Adult green sturgeon caught in Washington had been mainly feeding on sand lances (*Ammodytes hexapterus*) and callinassid shrimp (P. Foley, University of California, Davis, unpublished data, as cited in Moyle et al. 1992). In the Columbia River estuary, green sturgeon are known to feed on anchovies and clams (Moyle et al. 1995). The intestinal tract of an adult fish taken in Southern California contained the intact shell of a small live snail, *Olivella baetica* (Fitch and Schultz 1978). The stomachs of male green sturgeon collected in the Klamath River in 1995 contained a small gastropod, *Olivella pyna*, carapace remains of a juvenile Dungeness crab (*Cancer magister*), and the posterior portions of three ammocetes, presumably larvae of the Pacific lamprey (*Lampetra tridentata*) (Mulligan et al. 1996). A few stomachs contained gravel. The stomachs of green sturgeon have sometimes been found to be empty during spawning runs (USFWS 1980, 1982; Mulligan et al. 1996). Some species of sturgeon are known to be able to withstand long periods of starvation during periods of low food availability or spawning migrations (Dadswell 1979; Mason and Clugston 1993).

In the Sacramento-San Joaquin estuary, introduced invertebrate species are potential food sources for green sturgeon. In recent years, a major item in the white sturgeon diet has been the “overbite clam” (*Potamocorbula amurensis*), which became extraordinarily abundant in Suisun Bay following its invasion in the 1980s. White sturgeon that feed on *P. amurensis* have elevated levels of selenium, which has the potential to interfere with reproduction function (P. Moyle, 2001).

6. Natural Mortality

a. Predators

There are few known specific natural predators on large green sturgeon except for humans and

some large marine mammals (Fitch and Lavenburg 1971; Emmett et al. 1991). Eggs, larvae, and small juveniles are probably preyed upon by numerous fish species (Emmett et al. 1991). In the Columbia River downstream of McNary Dam, common carp (*Cyprinus carpio*), largescale suckers (*Catostomus macrocheilus*), and northern pikeminnow (*Ptychocheilus oregonensis*) have been collected with white sturgeon eggs in their stomachs (Duke et al. 1990).

b. Disease

The potential exists for disease to enter green sturgeon populations through the release of hatchery-raised white sturgeon. Diseases known to occur in white sturgeon hatcheries include bacterial diseases, protozoans, fungi, adenovirus, and the white sturgeon iridovirus (WSIV). Many of these causative diseases are found commonly in natural water systems, while the WSIV pathogen is thought to reside naturally in several wild populations of white sturgeon (USFWS 2000a).

The parasite *Cystoopsis acipenseri* (Nematoda) is prevalent in juvenile white sturgeons in the lower Columbia River (McCabe 1993), but it is unknown what impact this parasite has on sturgeon. Pat Foley of the University of California at Davis has done research on three external and three internal parasites on green sturgeon, noting that Asiatic populations share some unusual parasites with North American populations (P. Foley, University of California, Davis, pers. comm., as cited in Moyle et al. 1995).

B. DISTRIBUTION AND ABUNDANCE

1. California

In California, green sturgeon have been collected in small numbers in marine waters from the Oregon border to the Mexican border. Marine abundance of the species gradually increases northward of Point Conception. Adult fish have been observed in a handful of rivers, but spawning populations are known only in the Sacramento and Klamath river systems. Former spawning populations have apparently been eliminated from the Eel River and the South Fork Trinity River system, and possibly the San Joaquin River. The Klamath and Trinity rivers remain the principal spawning streams in California.

A rough estimate of annual abundance of adult green sturgeon in the San Francisco Bay system has been calculated based on a ratio of green sturgeon to white sturgeon (which have been more intensively studied) in the system. The adult green sturgeon population has been estimated to average 873 fish, based on surveys from 1954 to 1998. The California Department of Fish and Game estimated a continuous low annual occurrence of between 500 and 1000 adult green sturgeon in this system between 1967 and 1991 (CDFG 1994).

The only abundance estimates for the Klamath Basin come from inconsistent and under-reported data gathered by USFWS on the tribal gill net harvest from the Klamath River on the Yurok Reservation and the Hoopa Reservation on the Trinity River. An average harvest of 375 adult fish per year was recorded in the Klamath Basin during the 1980s and 1990s (USFWS 1981-1990, 1993, 2000). It is unknown what portion of the population this catch represents. See the Klamath fisheries section on page 42 and Appendix 2 on page 57 for more information about Klamath Basin catch statistics.

a. Southern California

Green sturgeon are not found in estuaries or rivers south of San Francisco Bay (Monaco et al. 1990). A small number of green sturgeon have been reported from the southern California coast, with individuals caught as far south as Ensenada, Baja California, Mexico (Fitch and Lavenberg 1971). Most of these fish were less than 100 cm TL (39 inches) and weighed less than 4 kg (8.8 pounds). The largest green sturgeon reported taken from the ocean south of Point Conception was a mature male 163 cm (64 inches) and 25.7 kg (56.5 pounds), caught by a commercial fisherman in 1975 off of Dana Point, Orange County (Fitch and Schultz 1978). Other records include a 3.3 kg fish taken in 1941 off Newport, Orange County (Roedel 1941); Fitch and Lavenberg (1971) report two 90 cm fish weighing 2.3 kg and 3 kg caught

off Belmont Pier, Long Beach, Los Angeles County; and a 94 cm, 3.5 kg fish caught off of Point Conception, Santa Barbara County. The Natural History Museum of Los Angeles County has the heads of four green sturgeon caught in marine waters near the coast in southern California (USFWS 2000).

Marine green sturgeon abundance gradually increases northward of Point Conception. They are occasionally caught in Monterey Bay (Moyle et al. 1992). A tagged green sturgeon has been recovered near Santa Cruz, Santa Cruz County (Miller 1972). Within the holdings of the California Academy of Sciences (CAS) is a skeleton collected at Moss Beach Landing, Monterey County, and a complete specimen acquired from the Santa Cruz Municipal Pier Aquarium (Moyle et al. 1992).

b. San Francisco Bay System

The San Francisco Bay system (including San Francisco Bay, San Pablo Bay, Suisun Bay, the Sacramento-San Joaquin Delta, and the Sacramento and San Joaquin river systems) harbors the southernmost spawning population of North American green sturgeon. Green sturgeon are known to spawn in the mainstem Sacramento River up to and just above Red Bluff Diversion Dam and in the lower Feather River, and may once have spawned in the San Joaquin River system. White sturgeon are the most abundant sturgeon in this system and green sturgeon have apparently always been less common (Ayles 1854; Jordan and Gilbert 1881).

Recent estimates of numbers of green sturgeon in this system have been predicated on their presumed abundance relative to white sturgeon, which are more intensively studied and counted. Between 1954 and 1987, CDFG measured and identified 13,982 sturgeon (both green and white) in the San Francisco Bay system. Based on these data, a green sturgeon to white sturgeon ratio of 1:5 was derived for fish less than 101 cm fork length (FL) and 1:78 for fish greater than 101 cm FL. It was assumed that sturgeon more than 101 cm (approximately 10 years old) were adults, that green and white sturgeon were equally vulnerable to capture by the various gear used during surveys, that green and white sturgeon populations fluctuate in a similar manner, and that the CDFG population estimates of white sturgeon (11,000 to 128,000 depending on the year) were accurate (Kohlhorst et al. 1991). Revising the estimates to include data through 1998 (CDFG 1999) yields a green sturgeon to white sturgeon ratio of 1:85 for legal size fish and a 1:13 ratio for sub-legal fish.¹¹ Ratios of adult green: white sturgeon during tagging studies have ranged from 1:50 to 1:100 (CDFG 1992).

The California Department of Fish and Game estimated a continuous low annual occurrence of between 500 and 1000 adult green sturgeon in this system between 1967 and 1991 (CDFG 1994). The mean annual abundance of adult (more than 101 cm FL) green sturgeon in this system from 1954 to 1998 has been estimated to be only 873 fish, ranging from an estimated 198 fish in 1954 to 1,906 fish in 1979 (Mills and Fisher 1994; CDFG 1999). Legal size green sturgeon abundance in 1998 was estimated to be only 418 fish. These numbers were ballpark estimates at best and may overestimate the adult green sturgeon population in the system (Moyle et al. 1992; P. Moyle, pers. comm., 2001). The numbers of juvenile sturgeon are presumably even more variable, depending on episodic reproduction (Kohlhorst et al. 1991).

i. S. F. Bay and Sacramento-San Joaquin Delta

San Francisco Bay

In south San Francisco Bay adult and juvenile green sturgeon are found year-round in the seawater and mixing zones (Aplin 1967; Miller 1972; D. Pearson, NMFS, Tiburon, CA, pers. comm., as cited by Monaco et al. 1990). In central San Francisco Bay (including Suisun and San Pablo Bays), adult green sturgeon are found from April through November in the seawater and mixing zones and rarely in the tidal fresh zone; juveniles are found from April through November in the seawater, mixing and tidal fresh zones; and larvae are found from February through June in the tidal fresh zone (Radtko 1966; Miller 1972; Kohlhorst 1976; J. Brennon, Moss Landing Marine Laboratories, Moss Landing, CA, and D. Kohlhorst and D. Stevens, CDFG, Stockton, CA, pers. comm., as cited by Monaco et al. 1990).

Historic records of green sturgeon taken from San Francisco Bay include the species type described by Ayres (1854). Collins (1892) noted a commercial catch of sturgeon (no species distinction was given) in the late 1800s, with fish taken chiefly in shallow flats on the north side of San Pablo Bay, in a bend west of Point Pinole, and in the Bay from Point Pinole to Point San Pablo (Skinner 1962). Chadwick (1959) tagged 25 green sturgeon in San Pablo Bay in 1954. During an investigation of the gill net fishery from 1954-1957, many green sturgeon were caught in nets in Suisun Bay and Carquinez Strait. The general upstream limit was observed to be about Middle Grounds in Suisun Bay.

¹¹

It is unknown whether the higher relative ratio of younger green sturgeon is due to past over-harvest of adult fish, a low survival rate of young fish, or easier capture of sub-adult fish.

However, two green sturgeon were taken by CDFG at Collinsville, 15 miles above Middle Grounds. Green sturgeon seemed to be most abundant in San Pablo Bay during the fall (Skinner 1962). Gill net and otter trawl surveys from 1963-1964 found 34 juveniles in San Pablo and Suisun Bays (Ganssle 1966). A single green sturgeon was taken in July 1965 west of Treasure Island (Aplin 1967), and 54 green sturgeon were collected in 1967 and 1968 in San Pablo Bay, all 101 cm or longer (Miller 1972). Three green sturgeon were collected during a survey in Richardson Bay from June 1972 to July 1973 (Green 1975).

Sacramento-San Joaquin Delta

Captures of larger young of year green sturgeon from the Delta were reported by Pycha (1956) and Schreiber (1960, 1962), and Radtke (1966) noted that 10 to 20 inch juveniles were common in the Delta, especially in the western Delta. Few juveniles have been caught until summertime, when fairly large catches have been taken with gill nets in the San Joaquin River at Santa Clara Shoal. The relatively high catch has suggested abrupt movement into this area, probably upriver from the Bay to feed (Radtke 1966). Fry (1973) thought the origin of these juveniles was probably the upper Sacramento River, but there was no evidence for this. Yolk sac stage sturgeon were captured in the Delta (and Suisun Bay, and the lower Sacramento River) from 1965-1968, but it was not known whether they were white or green sturgeon (Stevens and Miller 1970).

Juvenile green sturgeon have been found at the intakes of the Tracy Pumping Station (Wang 1986) and the federal Central Valley Project pumps (Moyle et al. 1992) in the south Delta. At the federal pumps, numbers of green sturgeon salvaged and recorded have ranged from 1374 fish in 1985 to none from 1988-1990. Variable, but declining numbers of green sturgeon have been captured almost yearly since 1968 at the State Pumping Facility, ranging from 7,311 fish salvaged in 1974 to 0 fish in 1986 and 1989 (Moyle et al. 1992).

Some of these fish are presumably released unharmed, but the actual survival rate is not known. See the section on entrainment on page 50 for Delta entrainment statistics.

ii. Sacramento River

From indirect evidence, it is inferred that green sturgeon in the San Francisco Bay system spawn mainly in the Sacramento River. The size and structure of green sturgeon eggs indicate that they are adapted for spawning in cold, low-silt water (USFWS 1995), conditions that likely once existed most consistently in the Sacramento and other rivers above where Shasta Dam is now located. Red Bluff Diversion Dam ("RBDD") has apparently been a barrier to green sturgeon migration until recently. Spawning times in the Sacramento River are likely from March through July, with a peak from mid-April to mid-June, based on times when adult sturgeon have been caught there (USFWS 1995).

Adult green sturgeon have been reported in the mainstem Sacramento River as far north as Red Bluff, Tehama County (river km 383) (Fry 1979). The Red Bluff Daily news carried photos of two large green sturgeon (one fish at 65 _ inches and 50 pounds, the other at 60+ inches and 85 pounds) caught under the Sacramento River Bridge in Red Bluff, on June 17 and June 18, 1966. The newspaper also reported bigger sturgeon landed in the same vicinity. A photo in the Sacramento Bee from June 27, 1966, shows a 66-inch, 50 pound green sturgeon caught in the Sacramento River south of Red Bluff Bridge (CDFG 1999). River guides have caught adult green sturgeon at the Anderson Hole, about 6 km above the Hamilton Bridge (Moyle et al. 1992). A dead adult green sturgeon was found on April 18, 1991, at river km 378 (approximately 5 km south of Dairyville, Tehama County), by biologists from the U. S. Fish and Wildlife Service (K. Brown, USFWS, pers. comm., as cited by Moyle et al. 1992). Live adult green sturgeon have been observed by USFWS crews surveying winter-run chinook salmon (*Oncorhynchus tshawytscha*) in the 16 km reach below Red Bluff Diversion Dam in 1991 and 1992 (K. Brown, USFWS, pers. comm., as cited by Moyle et al. 1992). In 1991, 20 large sturgeon were sighted between April 3 and May 21.

Small, young green sturgeon have been reported from a number of places on the lower river (Fry 1973; Moyle et al. 1992), including near Hamilton City, Glenn County (river km 317) (Fry 1979). 1162 juvenile and larval sturgeon were captured at the Glenn-Colusa fish screen in fyke and screw traps by the California Department of Fish and Game and the Glenn-Colusa Irrigation District from 1986 to 1994. The majority of the sturgeon were tentatively identified as *A. medirostris*. All of the 15 positively identified fish were green sturgeon, ranging from 7.6 to 41.9 cm in length (CDFG and GCID 1994).

Additionally, four young green sturgeon were collected at the Red Bluff Diversion Dam in late October 1991 (Moyle et al. 1992). During a two-week period in October 1991, these yearling green sturgeon (21.5-24.6 cm TL) were recovered from the diffuser on the East Ladder at RBDD. This was the first real evidence of green sturgeon spawning above RBDD. Specimens were collected and preserved (USFWS 2000). Juvenile sturgeon have been captured regularly in screw traps at RBDD by USFWS from

1995-1998. The majority of these fish are likely green sturgeon. Captured juveniles were between 24 and 70 mm mean FL (CDFG 1999).

In 1968, 41 larvae of indeterminate sturgeon species were caught in tow nets in the lower Sacramento River between Sacramento and Verona. One larvae was captured in Sacramento upstream of the confluence with the Feather River.

Feather River

Tributaries to the Sacramento River such as the Feather, Yuba, and American Rivers were claimed to have spawning green sturgeon by Wang (1986), but there was no direct evidence of spawning at that time. Pat Foley of the University of California, Davis, reported recent photographs of green sturgeon taken by sport fishers in the Feather River (USFWS 1995). Recent capture of larval green sturgeon in salmon out migrant traps indicates that the lower Feather River may prove to be a principal spawning area for the species (USFWS 1995).

iii. San Joaquin River

Moyle et al. (1992, 1995) believe that some spawning of green sturgeon may once have taken place in the lower San Joaquin River, since young green sturgeon have been taken at Santa Clara Shoal, Brannan Island State Recreational Area, Sacramento County (Radtko 1966), and a single specimen from the Old River is in the CAS collection (Moyle et al. 1992). Yolk sac stage sturgeon of an undetermined species were captured in the lower San Joaquin River from 1965 to 1968, and the amount of water flow at the time of capture indicated spawning upstream. However, Stevens and Miller (1970) did not consider this to be evidence of spawning in the San Joaquin, because the yolk sac sturgeon were caught in locations in the lower river where they could have emigrated through the Mokelumne River or through sloughs from the Sacramento River. Although there is no historic documentation, there is no reason why green sturgeon would not have used the San Joaquin system prior to the construction of large dams and significant water diversions, when suitable spawning and rearing habitat was accessible to anadromous fish. While green sturgeon are gone, white sturgeon are known to persist in the San Joaquin River, with a spawning population about one tenth the size of the Sacramento River white sturgeon population (Kohlhorst et al. 1991).

c. North Coast

North of San Francisco, green sturgeon are encountered in the ocean with greater frequency. Between San Francisco Bay and the Klamath River, it is likely that most records of sturgeon caught in rivers refer to green sturgeon (Moyle et al. 1992). However, most early references to sturgeon from this area failed to identify the species and some reports indicated white sturgeon to be more abundant (Fry 1979). As a result, much confusion has ensued as to the relative abundance of both species throughout this region.

Tomales Bay

Green sturgeon have been recorded from Tomales Bay and while numbers are small, they are roughly equal in abundance to white sturgeon (Moyle et al. 1992). However, Blunt (1980) noted that CDFG listed green sturgeon as common in Tomales Bay, and cited commercial trammel net fishing for green sturgeon at the mouth of Tomales Bay. Two green sturgeon were caught in Tomales Bay in August 1993 by halibut fishers (C. Knutson, pers. comm., as cited in CDFG 2000).

Bodega Bay

Bane and Bane (1971) noted that the species was not common within Bodega Bay, with only one known record. A tagged green sturgeon was recovered near Bodega Head (D. Kohlhorst, pers. comm., as cited by Moyle et al. 1992) and small numbers are taken incidentally by a near-shore halibut fishery

centered at Bodega Bay (C. Haugen, pers. comm., as cited by Moyle et al. 1992).

Noyo River

A single green sturgeon was collected from the Noyo River (D. Catania, pers. comm., as cited by Moyle et al. 1992). This may be the same specimen that is in the CAS collection, listed as taken from Fort Bragg in 1924 (CAS 1993).

i. Eel River

Historically, the only river with apparent spawning runs of green sturgeon in the Humboldt region was the Eel River. Accounts from 19th century newspapers provide the earliest evidence of sturgeon in the Eel River drainage. At this time sturgeon were reported from the mainstem Eel River, the South Fork Eel River, and the Van Duzen River (Wainwright 1965). For example on August 6, 1877, it was reported that "more than one hundred large sturgeon were killed in one deep place in the Eel River, near the mouth of Van Duzen in the last month." At the time, individual sturgeon were reported only if they were of exceptionally large size, which generally meant 2 to 2.5 m in length and in excess of 45 kg.¹² This would be large for a green sturgeon but not for a white sturgeon. Green sturgeon were also indicated as the Eel River species by a reference (May 19, 1887) to Native Americans capturing sturgeon because they knew "whites did not care for this sort of fish." This is at a time when there was a thriving commercial fishery for white sturgeon on the Columbia River and other locations, and green sturgeon flesh was considered inferior (Wainwright 1965).

The Eel River historically contained suitable spawning habitat for green sturgeon, and indirect evidence points to a historic spawning population in this system. In the early 1900s the Eel River still contained a lot of large deep holes and huge sturgeon. Well inland on the Eel River, upstream from Fort Seward was a quarter mile long hole known as the "sturgeon hole" (Mathison 1998).

In July 1950, two young sturgeon were collected in the mainstem Eel River; a dead sturgeon (identification not certain) 5.4 inches long taken from the mouth of the Van Duzen River at its confluence with the Eel River, and a 4.1 inch green sturgeon caught in a fyke net just upstream in the Eel River. In June 1950 several large sturgeon (up to 5 feet in length) were seen jumping (indicating courtship and spawning behavior) in tidewater in Dungan Pool, approximately 7 miles upstream from the ocean (Murphy and DeWitt 1951). After the 1964 flood on the Eel River, a crew with bulldozers filled in a large hole at Island Mountain (upstream of Alderpoint) to catch a sturgeon (Mathison 1998). Two additional young green sturgeon taken from unknown locations on the Eel River in 1967 are in the collection of the Humboldt State University Fish Museum (Moyle et al. 1992).

Further indication of historic spawning was provided by 475 juvenile green sturgeon (from 6.9 cm to more than 17 cm) found trapped in the mainstem Eel River from 1967 to 1970. These fish were found from late May through November between 30 and 100 km upriver - at Rio Dell, Holmes, McCann, Eel Rock, and at Ft. Seward (Puckett 1976). CDFG presumed green sturgeon were still spawning in the Eel River in 1968 (CDFG 2000).

Other than photos of an 86-inch, 98 pound green sturgeon caught in December 1978 at High Rock on the mainstem Eel River (CDFG files, Eureka), there were few confirmed records of green sturgeon in the Eel during the 1970s, 1980s, and early 1990s. Although green sturgeon have been found since then in the Eel River Delta (Monroe and Reynolds 1974; Blunt 1980), and adult and juvenile green sturgeon are

¹²

From newspaper accounts: a seven foot sturgeon weighing more than 100 pounds, was speared at the Blue Slide on the Eel River, and sold in Ferndale in October 1877; a "monster" sturgeon was seen thrashing in its struggle to pass up a riffle in August 1878 on the South Fork Eel River; the Eel River was remarked to contain "larger sturgeon than we have ever seen in any other county" in October 1878; a sturgeon was caught in the Van Duzen River in April 1883 which weighed 125 pounds, and was 74 inches long. (Wainwright 1965).

considered to be rare year-round residents in the seawater, mixing, and tidal fresh zones of the Eel River estuary (Fry 1979; D. McLeod and L. Preston, CDFG, Eureka, CA, pers. comm., as cited by Monaco et al. 1990), the Eel River population was presumed to have been lost. (Moyle et al. 1992; Nakamoto et al. 1995).

CDFG recently detected between one and four green sturgeon between McCann (at the confluence of the South Fork and Main Forks of the Eel) and Dos Rios (near Laytonville) on the mainstem Eel River. Green sturgeon were seen in this area in 1995, 1996, and 1997. They were not seen in 1998, but this was attributed to a lack of visibility due to high flows. (Scott Downey, CDFG, pers. comm. with Cynthia Elkins, EPIC, 1999). However, sightings of four fish do not indicate a viable population, and there is no recent evidence of spawning.¹³

ii. Humboldt County

Humboldt Bay

Historic records of sturgeon in the Humboldt Bay system (comprising Arcata Bay to the north and Humboldt Bay to the south) are almost exclusively green sturgeon. In August 1956, 50 green sturgeon ranging from 57.2 to 148.6 cm TL were tagged in Arcata Bay by CDFG (Moyle et al. 1992). Gotshall (1966) classified the green sturgeon as common in the channels of Humboldt Bay. Nine green sturgeon were collected by bottom trawl in August and September 1968, all from north Arcata Bay, ranging from 73 to 103 cm TL (Sopher 1974). However, Samuelson (1973) reported that ten years of trawl investigations (1960-1970) in South Arcata Bay produced only three green sturgeon.

The species was listed in 1980 as common in Humboldt Bay (Blunt 1980), and known to reside during the summer, fall, and winter in channels in Humboldt Bay, where fish up to 112 cm were found by the sport fishery and by research trawls (Gotshall et al. 1980). The Coast Oyster Company, Eureka, pulled an annual series of trawls in Arcata Bay in the late 1980s as a means of decreasing the abundance of bat rays, *Myliobatis californica*, in which green sturgeon were taken incidentally. Eight green sturgeon were collected in 1988 and 1989 ranging from 78 to 114 cm TL. One large individual, 178 cm TL (70 inches) and 18.2 kg (40 pounds), was returned to the bay. Only a single white sturgeon, 100-150 cm estimated TL, was captured during these trawls (Moyle et al. 1992). Adult and juvenile green sturgeon were recently considered common in the seawater and mixing zones of Humboldt Bay, adults July through April, and juveniles July through December (Fry 1979; Gotshall et al. 1980; Sopher 1974; R. Warner, CDFG, Eureka, CA, and R. Barnhart, USFWS Coop. Fish Research Unit, Arcata, CA, pers. comm., as cited by Monaco et al. 1990).

Mad River

Green sturgeon have been reported from the Mad River, although this river is probably too small to have ever supported a spawning run (Fry 1979). Recent evidence of their presence is scant and any green sturgeon in the Mad River would likely be limited to the estuary (Moyle et al. 1992).

Humboldt County Lagoons

An occasional green sturgeon is encountered in the coastal lagoons of Humboldt County (Moyle et al. 1992). Big Lagoon and Stone Lagoon are connected to the ocean during part of the year and any migrating sturgeon may gain entry at this time. In June 1991, a 120 cm green sturgeon was gill netted in Stone Lagoon (Moyle et al. 1992).

iii. Klamath-Trinity River System

The largest spawning population of green sturgeon in California is in the Klamath River Basin. Green sturgeon are known to spawn in the Klamath and Trinity Rivers, but have been eliminated from the South Fork Trinity River. While historic sizes of green and white sturgeon runs are not known, recent numbers of green sturgeon have far exceeded those of white sturgeon in the basin (USFWS 1993).

The only population information available for this system is the annual USFWS harvest estimates from tribal gill net fisheries. These estimates are biased low by variable and inconsistent sampling effort based on volunteered data. Additionally, some harvest occurs prior to the annual monitoring activities of the USFWS, and tribal harvest in the Trinity River Basin by the Hoopa Valley Tribe has not always been accounted for. The estimated annual harvest for the Klamath system has averaged 375 fish from 1980 to 1999, but it is unknown what portion of the population this represents.¹⁴

See the section on Klamath fisheries on page 42 and

¹³

While the Eel River apparently does not currently support a viable green sturgeon spawning population, it may have the greatest potential for recovery actions for the species, since adult fish are still seen well upstream in the system.

¹⁴

There may be some indication of decline, with the average annual catch from 1980-1989 being 483 fish, whereas from 1990-1999 it was only 267 fish. It is unknown whether fishing effort or catch sampling have been consistent.

Appendix S2 on page 57 for more detailed catch statistics. If the tribal fishery has a 50% exploitation rate, the annual spawning escapement would also be 375 fish. Beach seining, set lining, gill netting, and trawling surveys have not been significant or consistent enough to give accurate population estimates.

The majority of harvested adults are caught during their upstream spawning run in late spring and summer, with small numbers of spawned-out downstream migrants caught in summer and fall net fisheries. Downstream migration of post-spawners occurs well into fall and early winter. Male fish are generally smaller and more numerous than the females, with a recorded average length of 163 cm, as compared to 188 cm for females. Spawner ages have ranged from 15 to 40 years. In two studies of Klamath River fish, spawning females averaged 28 and 32 years old, and males 21 and 23 years. (USFWS 1982, 1983; Nakamoto et al. 1995).

Klamath River Estuary

Both green and white sturgeon are found in the Klamath River Estuary (Snyder 1908; USFWS 1980-91), but white sturgeon are taken infrequently and presumed not to spawn in the river (USFWS 1982). All white sturgeon caught in the river have been taken by gillnet in the lower 6 km of river, making it likely that some of these fish were coastal migrants originating from some other river system (USFWS 1981). Historic records of sturgeon in the estuary include a large fish (no species given) taken at the mouth of the Klamath in May of 1887 (Wainwright 1965) and a "large specimen" taken near the mouth in June or July of 1897 (Snyder 1907).

Adult and juvenile green sturgeon currently are commonly found in the seawater, mixing, and tidal fresh zones of the Klamath River estuary, adults February through November, and juveniles year-round (Fry 1979; CH2M Hill 1985; USFWS 1987, 1988; T. Kisanuki and C. Tuss, USFWS, Arcata, CA, and M. Pisano, CDFG, Arcata, CA, pers. comm., as cited by Monaco et al. 1990). Most juveniles in the system have been recovered by seining operations directed at salmonids in the tidewater (USFWS 2000; CDFG 2000).

Klamath River

A sturgeon investigation program initiated in 1979 by USFWS found that almost all sturgeon occurring above the estuary in the Klamath River were green sturgeon (USFWS 1980-83). Sturgeon primarily use the mainstem Klamath River and mainstem Trinity River, but have also been seen in the lower portion of the Salmon River. Both adults and juveniles have been identified in the mainstem Klamath River. Green sturgeon migrate up the Klamath River between late February and late July. The spawning period is March through July, with a peak from mid-April to mid-June (Emmett et al. 1991; USFWS 1999).

Adults are taken annually, spring and summer, by a growing tribal gill net fishery. The numbers average less than 500 fish per year (see the section on Klamath fisheries on page 42). The tribal fishery is a relatively recent development and will likely expand as increased restrictions are placed on the harvest of depleted salmon populations in the rivers (Moyle et al. 1992), thus increasing the likelihood for future green sturgeon declines (USFWS 1995). See the section below on Klamath river fisheries.

Green sturgeon have been taken by sport fishers as far inland as Happy Camp (river km 172) (Fry 1979; USFWS 1981). The presence of very small sturgeon well upstream in the Klamath system suggests that adults go well inland to spawn (Fry 1979). However, the apparent limit for the spawning migration is Ishi Pishi Falls, upriver from Somes Bar, Siskiyou County (approximately river km 113). A pool known as "the Sturgeon Hole" (at river km 96, 1.5 km upstream from Orleans, Humboldt County) is apparently a major spawning site, because leaping and other "frantic behavior" indicative of courtship and spawning are often observed there during spring and early summer (Moyle 1976).

Out migrant traps operated by USFWS from 1989 to 1999 indicate that juvenile green sturgeon out migrate from late May to late July on the Klamath River, with the peak period in early July.¹⁵ Klamath

¹⁵

Out-migrants on the Klamath numbered 0 in 1989, 0 in 1990, 7 in 1991, 23 in 1992, 42 in 1993, 6 in 1994,

emigrants ranged from 1.5 to 11.5 cm in length, with the majority of fish 3 to 4.5 cm in length (data from J. Craig, as cited in USFWS 2000).

Salmon River

The Salmon River is a second order stream entering the Klamath River at Somes Bar (river km 106). The water in this river is generally clear and becomes turbid only during high run off periods. Adult sturgeon have been seen swimming in this river by observers standing on bluffs overhead. The approximate limit to upriver migration is at the mouth of Wooley Creek, a third order stream (river km 8). Juveniles have yet to be found in the Salmon River, however. (Moyle et al. 1992).

Trinity River

The Trinity River enters the Klamath River at Weitchpec (river km 70). Both adults and juveniles have been identified from the Trinity. Some juvenile green sturgeon have been captured in annual surveys in the mainstem Trinity as high up as Big Bar (Moyle et al. 1992; USFWS 1999), but the upstream limit of known spawning is about Grays Falls, near Burnt Ranch, Trinity County (river km 72).

Historic records on the Klamath River include a “young specimen” in the Stanford University collection taken before 1897 from Hoopa Valley on the Trinity River (Gilbert 1897). Over 200 green sturgeon, between 7 and 29 cm TL, were captured near Willow Creek (river km 51), Humboldt County, incidental to a salmonid migration study in July, August, and September of 1968 (Healy 1970).

Out migrant traps operated by USFWS from 1989 to 1999 indicate that juvenile green sturgeon out migrate from early June to early September on the Trinity River, with the peak in early July.¹⁶ Trinity emigrants ranged from 2.5 to 14.5 cm in length, with the majority of fish 3 to 4.5 cm in length (data from J. Craig, as cited in USFWS 2000).

South Fork Trinity River

Historically, sturgeon were reported to use the South Fork Trinity River, a third order stream entering above Willow Creek (river km 51) (USFWS 1981). Oral histories from old time residents confirm this (Moyle et al. 1992). However, a large flood in 1964 had devastating effects on anadromous fish habitat in this sub-basin (United States Department of the Interior 1985, as cited by Moyle et al. 1992). Millions of cubic yards of soil were moved into the South Fork Trinity River and its tributaries, resulting in channel widening and a loss of depth. This event, along with other changes in morphology, has apparently eliminated suitable sturgeon habitat, and there have been no recent sightings from this watershed (Moyle et al. 1992). Green sturgeon appear to have lost this spawning area.

iv. Del Norte County

Lake Earl

Green sturgeon have been taken during gill net sampling in Lake Earl (Blunt 1980; D. McCloud, CDFG, Eureka, CA, pers. comm., as cited by Moyle et al. 1992). Lake Earl is located along the coast of Del Norte County, 8 km north of Crescent City and 11 km south of the mouth of the Smith River. It is connected by a narrow channel to Lake Talawa, a smaller lake directly to the west. A sand spit, which is occasionally breached by winter storms or humans, separates Lake Talawa from the ocean. Green sturgeon enter at this time and become trapped after the sand spit is rebuilt (Monroe et al. 1975).

42 in 1995, 676 in 1996, 139 in 1997, 9 in 1998, and 94 in 1999. 1989-1992 were low water years, 1994 was a drought year, and 1995-1999 had above average flows.

Out-migrants on the Trinity numbered 2 in 1989, 0 in 1990, 6 in 1991, 43 in 1992, 4 in 1993, 10 in 1994, 1 in 1995, 43 in 1996, 49 in 1997, 24 in 1998, and 0 in 1999. 1989-1992 were low water years, 1994 was a drought year, and 1995-1999 had above average flows.

Smith River

The Smith River is the northernmost river along the California coast, entering the ocean approximately 5 km south of the Oregon border. Blunt (1980) included green sturgeon in an inventory of anadromous species found in Smith River. According to CDFG, green sturgeon occasionally enter the estuary, probably to feed; there is no record of spawning in the river (Monroe et al. 1975). Research seining of the Smith River estuary by ODFW in 1972 turned up no sturgeon, but bottom habitat in deep areas suitable for sturgeon was not seined. Before 1973, documentation of green sturgeon in the Smith River was confined to the area below the confluence of the Middle and South Forks (river km 27). Unconfirmed sightings were reported near Gasquet, below the confluence of the North and Middle Forks (river km 40). In December 1973, a green sturgeon four feet in length was observed in Patrick's Creek, an upstream tributary to the Middle Fork, about 55 km from the ocean (report by Loius H. Carufel, U. S. Forest Service Fisheries Biologist, Six Rivers National Forest, in CDFG 2000). Juveniles have not been found and green sturgeon are presumed not to spawn in the Smith River system (Moyle et al. 1992).

2. Oregon

Green sturgeon probably occur in all open Oregon estuaries, mostly during the summer, likely moving in and out of estuaries up and down the coast. They are found in fresh water in Oregon in the lower Rogue, Umpqua, and Columbia River systems, but are only believed to reproduce in the Rogue River.

Some fisheries biologists believe there may possibly be spawning in other coastal Oregon rivers, such as the Umpqua, Coos, and Coquille Rivers (King 2000) - but there is no evidence of this. The sizes (72-142 cm mean FL) of small numbers (282 fish) of green sturgeon tagged in Tillamook, Yaquina, Coos, and Winchester Bays from 1997-2000 do not indicate spawning populations (ODFW 2000a). It is believed that the Tillamook, Coos, Umpqua, and Yaquina river systems have no suitable spawning habitat for white sturgeon (Whisler et al. 1999), and therefore likely none for green sturgeon. The lack of small white sturgeon (less than 82 cm) during surveys of the bays of these river systems (Watts and Melcher 1997; Whisler et al. 1999) confirms this. In contrast, small white sturgeon are abundant and observed on a consistent basis in the Columbia River (fishers and gear used in the Columbia are similar to the coastal estuaries), where there is a known reproducing population of white sturgeon. It is therefore highly likely that there is no suitable green sturgeon spawning habitat in these coastal estuaries and rivers.

a. South Coast Bays & Estuaries

Other than 9 green sturgeon reported caught by sport fishers in 1989, 3 fish in 1991, and 4 fish in 1992 in the Chetco River Estuary (ODFW 2000), recent sportfishery data for the south coast could not be located.

b. Rogue River

The northernmost probable spawning population of North American green sturgeon is in the Rogue River. However, there have been no direct observations of spawning activity or collections of eggs from this river. The size of the Rogue population is unknown, but probably varies with movement of fish in and out of the system (ODFW 2000b). Green sturgeon ranging from 6 inches through adults are seen in the Rogue River, although they do not seem to range far into the system. There is a white sturgeon fishery at about river mile 40, but green sturgeon are not seen this far up (Al Smith, ODFW, pers. comm., as cited in ODFW 2000).

A persistent spawning population in the Rogue is probable but not definite. Anadromous salmonids all have a significant degree of straying, and some of this can be expected for green sturgeon. It is possible that small juveniles in the Rogue River Estuary occur because of its close proximity to the Klamath River mouth, with green sturgeon sighted due to straying from the nearby Klamath River adult population. There does not seem to be evidence that the Rogue is a river with a persistent annual

spawning population of significant numbers of green sturgeon. There are no reliable population estimates of green sturgeon in the Rogue River, but numbers are unlikely to be high (P. Moyle pers. comm., 2001). There have been consistent recent observations of relatively few fish.

Adult and juvenile green sturgeon are reported to be found year-round in the seawater, mixing, and tidal fresh zones of the Rogue River estuary (Ratti 1979; A. Riikula, ODFW, Gold Beach, OR, pers. comm., as cited by Monaco et al. 1990). It is not clear whether these have been very small juveniles or the same large juveniles that are coastal migrants and are found in areas without spawning populations. White sturgeon also occur in the estuary (Thompson and Fortune 1970; Ratti 1979). ODFW has conducted a Rogue River estuary salmonid evaluation since 1969, and green sturgeon are incidentally captured each year in this monitoring program. Juvenile and adult green sturgeon are also captured in an ODFW beach seining project at Huntley Park (Al Smith, ODFW, pers. comm., as cited in USFWS 1990).

An annual average of only 23 green sturgeon were caught in the Rogue River by sport fishers from 1986 to 1994¹⁷; this fairly small number indicates that the Rogue likely does not harbor a "major" population (ODFW 2000, 2000a). More recent sport fishing data for the Rogue River could not be located.

c. Coos Bay

Adult and juvenile green sturgeon have been commonly found year-round in the seawater and mixing zones of Coos Bay (Cummings and Schwartz 1971; Gaumer et al. 1973a; Roye 1979; D. Bottom, ODFW, Corvallis, OR, and W. Mullarkey, ODFW, Charleston, OR, pers. comm., as cited by Monaco et al. 1990). White sturgeon also have been known to occur in Coos Bay (Gaumer et al. 1973a). It is believed that the Coos river system has no suitable spawning habitat for white sturgeon (Whisler et al. 1999), and therefore none for green sturgeon. The lack of small white sturgeon (less than 82 cm) during surveys of Coos Bay (Watts and Melcher 1997; Whisler et al. 1999) confirms this.

Cummings and Schwartz (1971) concluded that green sturgeon penetrate the Coos Bay estuary up to almost 40 km from the ocean based on June-September 1970 surveys and their review of historical records. According to Roye (1979) green sturgeon inhabited the marine areas, Lower Bay, Upper Bay, and riverine habitats up to river km 27-48. Annual gill net surveys by ODFW captured green sturgeon in Coos Bay, but white sturgeon were absent in the years prior to 1990 (Al Smith, ODFW, as cited by USFWS 1990a). Tagging operations in 1998, however, found 50 white sturgeon and only one green sturgeon (Whisler et al. 1999).

An annual average of 7 green sturgeon were caught by sport fishers in the lower Coos River system from 1986 to 1994¹⁸ (ODFW 2000, 2000a). Other than 17 green sturgeon caught in 1996 in Coos River and Bay (ODFW 2000), more recent sport fishing data for the Coos River could not be located.

d. Umpqua River/Winchester Bay

Sturgeon (both green and white) were historically very abundant in the Umpqua River, especially in the lower river estuary below the present site of Reedsport. An abundance of adult green sturgeon in the lower Umpqua and their relative scarcity in the upper river in the early days tends to corroborate the probability that most green sturgeon spawned in the lower reach of river between Reedsport and the "big bend" five miles downstream. The lower river was avoided by fishers during seasons when the sturgeon were abundant because the large fish tore salmon nets, and consequently the fish were considered a menace and destroyed. At times sturgeon were deliberately sought after for the sole purpose of destroying them. Sturgeon had no market value on the Umpqua until the construction of the railroad, about 1916, permitted the shipping of fresh fish to the markets. By that time the species had become so scarce as to make a targeted sturgeon fishery unprofitable. (FCO and OSGC 1946).

Up until 1948 sturgeon were caught incidentally in a gill net fishery primarily for chinook, silver salmon, and shad. Both white and green sturgeon were taken, but green were more abundant - landings of green sturgeon were about ten times the poundage of white sturgeon. The catch prior to 1928, by which time sturgeon were already scarce, is not known. From 1928-1946, almost 20,000 pounds of green sturgeon were landed in the Umpqua River.¹⁹ An average of 1152 pounds per

¹⁷ Recorded catch was 6 fish in 1986, 41 fish in 1987, 56 fish in 1988, 35 fish in 1989, 24 fish in 1990, 10 fish in 1991, 4 fish in 1992, 22 fish in 1993, and 8 fish in 1994.

¹⁸ Recorded catch was 6 fish in 1986, 6 fish in 1987, 4 fish in 1988, 0 fish in 1989, 3 fish in 1990, 13 fish in 1991, 15 fish in 1992, 0 fish in 1993, and 16 fish in 1994.

¹⁹ Landings in pounds per year were 1760 in 1928, 1226 in 1929, 2726 in 1930, 628 in 1931, 2042 in 1932, 1173 in 1933, 470 in 1934, 476 in 1935, 1019 in 1936, 540 in 1937, 997 in 1938, 929 in 1939, 433 in 1940, 197 in 1941, 696 in 1942, 727 in 1943, 875 in 1944, 837 in 1945, and approximately 525 in 1946.

year were caught from 1928-1937, and an average of only 691 pounds per year from 1938-1946.²⁰ (FCO and OSGC 1946).

The approximate age of fish caught in 1946 was estimated using a method of age determination developed by Harkness (1923). Under regulation at the time, sturgeon less than four feet in length could not be taken, so that the size of fish represented by commercial landings was the weight of those more than four feet long, and not the average of the catch. Small sturgeon less than four feet were still common on the lower Umpqua in 1946. The legal fish landed in 1946 weighed an average of 26.3 pounds, and were estimated to be from 31 to 52 years of age, with an average age of 37 years. Only twenty legal size fish were taken in 1946. (FCO and OSGC 1946).

The Fish Commission of Oregon concluded that the fishery was removing sturgeon before they were able to reach their most fecund size, and that it was “obvious that the fish contributing to the catch were the progeny of the once abundant stocks present in the Umpqua prior to 1918.” The Commission recommended that sturgeon of all sizes be protected from commercial fishing and angling for an indefinite period on the Umpqua, estimating that it would take “several score” years of no fishing to rehabilitate this fishery. There was no sport fishery for sturgeon at that time. (FCO and OSGC 1946).

By 1972 green and white sturgeon were called “two of the least common species of fish” in the Umpqua basin, and green sturgeon were noted by then to be less common than the white (Lauman et al. 1972). The spawning range was restricted to the tidewater sections of the Umpqua, with spawning areas marked as the Umpqua River upstream to about 4 km below Scottsburg (approximately river km 36), and approximately 11 km up the Smith River (a tributary to the Umpqua at approximately river km 15). (Lauman et al. 1972).

Sturgeon supported a sport fishery on the Umpqua by early 1972, with an annual estimated landing of 600 sturgeon (most of which were likely white sturgeon, as they were by now the more common species in the system). Sturgeon were taken primarily in January-February and June-August, with spawning occurring primarily in May and June. Troll fishers operating from Winchester Bay in the Umpqua estuary harvested 250 pounds of sturgeon in 1970, most of which were likely white sturgeon (Lauman et al. 1972). Boat anglers caught 130 green sturgeon (and 116 white sturgeon) in 1971, all in July, between Winchester Point and Highway 101 (Gaumer et al. 1973b).

Research seining of the Umpqua and Smith River estuaries by ODFW in 1972 turned up no sturgeon, but bottom habitat in deep areas suitable for sturgeon was not seined. Seining operations from 1977-1986 had similar results (Johnson et al. 1986), although green sturgeon were noted to be known common inhabitants of the estuary by Mullen (1977). Adult green sturgeon were recently presumed to be commonly found year-round and juveniles rarely found in the seawater and mixing zones of the Umpqua River estuary (FCO and OSGC 1946, Gaumer et al. 1973b, Johnson et al. 1986, Lauman et al. 1972, Mullen 1977; J. Johnson, ODFW, Reedsport, OR, pers. comm., as cited by Monaco et al. 1990).

Although the sport fishery in the Umpqua targets white sturgeon (Al Smith, ODFW, as cited USFWS 1990a), an annual average of 124 green sturgeon were caught by sport fishers from 1986-1996²¹ (ODFW 2000, 2000a). More recent sport fishing data for the Umpqua River could not be located.

Twenty two green sturgeon were caught by researchers and tagged in Umpqua Bay from 1991-1998, with no indication of returns (Whisler et al. 1999; ODFW 2000a). Tagged green sturgeon from San Pablo Bay and Columbia River white sturgeon have been recovered in Winchester Bay (Whisler et al. 1999).

e. Middle Coast Bays & Estuaries

²⁰

Average white sturgeon landings similarly declined from 116 pounds per year from 1928-1937 to 47 pounds per year from 1938-1946.

²¹

The recorded catch was 85 fish in 1986, 70 fish in 1987, 99 fish in 1988, 103 fish in 1989, 109 fish in 1990, 221 fish in 1991, 142 fish in 1992, 188 fish in 1993, 120 fish in 1994, 66 fish in 1995, and 157 fish in 1996.

Siltcoos Lake

Both green and white sturgeon have been occasionally found in Siltcoos Lake, which is connected to the ocean by Siltcoos River (Smith and Lauman 1972).

Siuslaw River Estuary

Adult and juvenile green sturgeon have been found, but are considered rare, in the seawater zones of the Siuslaw River estuary (J. McLeod, ODFW, Florence, OR, J. Butler and G. Stewart, ODFW, Newport, OR, pers. comm., as cited by Monaco et al. 1990). An annual average of 3 green sturgeon were caught by in the Siuslaw River by sport fishers from 1986-199522 (ODFW 2000, 2000a). More recent sport fishing data for the Siuslaw River could not be located.

Alsea River Estuary

Adult and juvenile green sturgeon have been found, but are considered rare, in the seawater zones of the Alsea River estuary (J. McLeod, ODFW, Florence, OR, J. Butler and G. Stewart, ODFW, Newport, OR, pers. comm., as cited by Monaco et al. 1990). Other than 17 green sturgeon caught by sport fishers in 1989, 3 fish in 1990, and 3 fish caught in 1996 in the Alsea River basin (ODFW 2000), more recent sport fishing data for the Alsea River could not be located.

Yaquina Bay Estuary

Green sturgeon were reported by Wydoski and Whitney (1979) to be captured easily (10-15 per hour) with experimental gillnets in the Yaquina River near Toledo, Oregon (approximately river km 18) during September 1968. Bottom and Forsberg (1978) reported green sturgeon present in Yaquina Bay based on data they surveyed from Gaumer et al. (1974), Jerry Butler, ODFW (telephone conversation 1978), and Wally DeBen, USEPA (telephone conversation 1978); but concluded that larval green sturgeon were absent from the estuary based on data reported by Percy and Myers (1974). It is believed that the Yaquina River system has no suitable spawning habitat for white sturgeon (Whisler et al. 1999), and therefore none for green sturgeon. The lack of small white sturgeon (less than 82 cm) during surveys of Yaquina Bay (Watts and Melcher 1997; Whisler et al. 1999) confirms this.

Adult and juvenile green sturgeon are currently considered rare in the seawater, mixing, and tidal fresh zones of Yaquina Bay (Gaumer et al. 1974; W. DeBen, U. S. Environmental Protection Agency, Newport, OR, and H. Horton, Oregon State University, Corvallis, OR, pers. comm., as cited by Monaco et al. 1990).

An annual average of 11 green sturgeon were caught by sport fishers from 1986-1994 in Yaquina Bay and River23 (ODFW 2000, 2000a). Other than 6 green sturgeon caught in 1996 (ODFW 2000), more recent sport fishing data for the Yaquina River could not be located.

Five green sturgeon were caught and tagged in Yaquina Bay from 1991-1994 (ODFW 2000a). Several tagged green sturgeon (no indication of origin) have been recaptured in Yaquina Bay (Al Smith, ODFW, as cited in USFWS 1990a).

Siletz River Estuary

Gaumer et al. (1973c) noted that sturgeon (no species differentiated) were known to reside in the Siletz River estuary channels, but sturgeon were not mentioned in a 1979 Estuary Inventory Report (Starr 1979) by ODFW. Green sturgeon have apparently been found, but are considered rare, in the Siletz River Estuary (Starr 1979; G. Stewart, ODFW, Newport, OR, pers. comm., as cited by Monaco et al. 1990). An annual average of 13 green sturgeon were caught by sport fishers in the Siletz River system from 1986-198824 (ODFW 2000, 2000a). No catches were recorded from 1989 to 1994, and more recent sport fishing data for the Siletz River could not be located.

Nestucca River

Sport fishers reported catching 4 green sturgeon in the Nestucca River in 1993 (ODFW 2000).

f.....North Coast Bays & Estuaries

Netarts Bay

-
- 22 The recorded catch was 6 fish in 1986, 6 fish in 1987, 0 fish in 1988, 0 fish in 1989, 3 fish in 1990, 6 fish in 1991, 0 fish in 1992, 0 fish in 1993, 4 fish in 1994, and 3 fish in 1995.
- 23 The recorded catch was 0 fish in 1986 and 1987, 26 fish in 1988, 21 fish in 1989, 3 fish in 1990, 13 fish in 1991, 16 fish in 1992, 16 fish in 1993, and 0 fish in 1994.
- 24 The recorded catch was 25 fish in 1986, 6 fish in 1987, and 9 fish in 1988.

Green sturgeon are not found in Netarts Bay (A. Chung, Oregon State University, Corvallis, OR, pers. comm., as cited by Monaco et al. 1990).

Tillamook Bay

Only one green sturgeon was caught in research trawls from 1974 to 1976 in Tillamook Bay (Forsberg et al. 1977; Bottom and Forsberg 1978). An annual average of 18 green sturgeon were caught by sport fishers from 1986-1996²⁵ (ODFW 2000, 2000a). More recent sport fishing data for the Tillamook River could not be located.

Eleven green sturgeon were caught and tagged in Tillamook Bay from 1991-1998 (Watts and Melcher 1997; Whisler et al. 1999).

Nehalem Bay

Green sturgeon are considered rare but generally not found in Nehalem Bay (W. Knispel, ODFW, Seaside, OR, pers. comm., as cited by Monaco et al. 1990). An annual average of 19 green sturgeon were caught by sport fishers in Nehalem Bay and River from 1986-1995²⁶ (ODFW 2000, 2000a). More recent sport fishing data for the Nehalem River could not be located.

g. Columbia River System

Green sturgeon have always been less abundant in the Columbia River system than white sturgeon, which have anadromous spawning populations in the lower river and landlocked populations above dams. Green sturgeon were likely as over-fished as white sturgeon in the late 1800s (see the section on fisheries below for accounts of the well-documented collapse of Columbia River white sturgeon fisheries), although there is no historic data on the species. Green sturgeon once ranged at least 225 km (140 miles) up the Columbia River before the construction of large dams (Wydoski and Whitney 1979; ODFW 1991), although now they are rarely found above Puget Island (approximately river km 60) (King and Norman 1991). No green sturgeon eggs have been recovered during searches between river km 17 and Bonneville Dam (~ river km 225) (Chuck Tracy, WDFW, pers. comm., as cited in USFWS 1990). Green sturgeon are reported by the Oregon Department of Fish and Wildlife to be "relatively abundant" and stable in numbers (no numbers are given) in the Columbia River (ODFW 2000b).

Today, the majority of green sturgeon harvest in North America occurs in the Columbia River system and Washington coastal areas. Sturgeon landings are recorded from the Columbia River estuary and from Grays Harbor and Willapa Bay, Washington, to the immediate north of the estuary. There has never been any evidence of green sturgeon spawning in the rivers of this region, and it is likely that the fish harvested here migrated from Oregon or California, as indicated by limited recaptures of tagged sturgeon. Further evidence of the lack of local recruitment into the fishery is that few juvenile sturgeon (less than 1.3 m) are caught (Emmett et al. 1991). Any spawning utilization of the upper harbor or lower river is questionable since ripe fish have rarely, if ever, been taken in the area, and green sturgeon here are noted to definitely prefer salt or brackish water and avoid fresh water (Deschamps et al. 1970). Recent estimates are that up to 2,000 adult green sturgeon have been harvested annually during the last two decades, but it is unknown what portion this represents of the fish in the system. See Appendix 2 on page 57 for lower Columbia River catch statistics.

Adult green sturgeon are seasonally common in the seawater and mixing zones of the Columbia River estuary (ODFW and WDF 1987; S. King, ODFW, Clackamas, OR, and G. McCabe, Jr., NMFS, Hammond, OR, pers. comm., as cited by Monaco et al. 1990). Green sturgeon are especially abundant from early May through mid-October, while white sturgeon are present mainly from late September through early April (Beamesderfer 1997).

Willamette River

The Willamette River is a large tributary that enters the Columbia River at approximately river km 150, downstream of Bonneville Dam. According to ODFW, green sturgeon are found in the lower Willamette River (ODFW 2000b).

3. Washington

Both green sturgeon and white sturgeon are present coastally in Washington state. Green sturgeon do not spawn in any of the Washington river systems although they were seasonally abundant as of 1995 in a few Washington bays and estuaries (WDFW 1995).

a. Willapa Bay

²⁵ The recorded catch was 25 fish in 1986, 12 fish in 1987, 43 fish in 1988, 0 fish in 1989, 6 fish in 1990, 40 fish in 1991, 12 fish in 1992, 16 fish in 1993, 12 fish in 1994, 3 fish in 1995, and 24 fish in 1996.

²⁶ The recorded catch was 0 fish in 1986, 29 fish in 1987, 21 fish in 1988, 17 fish in 1989, 6 fish in 1990, 60 fish in 1991, 4 fish in 1992, 47 fish in 1993, 0 fish in 1994, and 6 fish in 1995.

Adult green sturgeon are common in the seawater and mixing zones of Willapa Bay during high salinity periods (ODFW and WDF 1987; S. King, ODFW, Clackamas, OR, and G. McCabe, Jr., NMFS, Hammond, OR, pers. comm., as cited by Monaco et al. 1990). Green sturgeon are especially abundant from early May through mid-October (Beamesderfer 1997). Willapa Bay is a critical summer feeding area for green sturgeon, where they are targeted by the commercial fishery when the rains start (S. Wright, pers. comm. 2000). There were some large catches of green sturgeon in Willapa Bay (up to 3-4,000 fish annually) in the late 1960s and early 1970s (S. Wright, pers. comm. 2000). An average of 1,000 adult green sturgeon were caught each year in Willapa Bay during the 1980s, and less than 400 annually during the 1990s. The commercial catches of green sturgeon from Willapa Bay are discussed below in the fisheries section on page 44 and in Appendix 4 on page 60.

b. Grays Harbor

Adult green sturgeon are common in the seawater and mixing zones of Grays Harbor during high salinity periods (ODFW and WDF 1987; S. King, ODFW, Clackamas, OR, and G. McCabe, Jr., NMFS, Hammond, OR, pers. comm., as cited by Monaco et al. 1990). Green sturgeon are especially abundant from July through early October, when the highest catches are made by the Grays Harbor gill net fishery, but generally avoid the area during the remainder of the year when salinities are lower. There has been a tremendous amount of studies of green sturgeon in Grays Harbor, but no juveniles have ever been found (S. Wright, pers. comm. 2000). The species is not known to utilize the lower Chehalis River (which empties into Grays Harbor) at any time (Deschamps et al. 1970). Grays Harbor is the only area other than the Klamath River with a tribal fishery for green sturgeon. An average of 600 adult green sturgeon have been caught in Grays Harbor each year during the last two decades. The commercial and tribal catches of green sturgeon from Grays Harbor are discussed below in the fisheries section on page 44 and in Appendix 4 on page 60.

c. Puget Sound

Green sturgeon are not found in Skagit Bay or Hood Canal (DeLacy et al. 1972; Miller and Borton 1980), and apparently have never been common in Puget Sound (Jordan and Starks 1895; DeLacy et al. 1972; Miller and Borton 1980).

4. Canada

Green sturgeon were given "rare" status in Canada in 1987 by the Committee on the Status of Endangered Wildlife in Canada, based on a lack of general information on their biology and their uncommonness (Houston 1988). Green sturgeon have been caught as by-catch off the west coast of Vancouver Island, sometimes with huge catches, but trawlers report recent steep declines in catch (Glavin 1996).

There are freshwater records of green sturgeon from the mouths of the Fraser, Skeena, and Nass Rivers (McPhail and Carveth 1993). Green sturgeon were historically quite abundant in the Fraser River, although there was no direct evidence of spawning. Green sturgeon populations in the Fraser River have collapsed to the point where they are now rarely seen (Slack and Stace-Smith 1996). Dramatic declines in abundance and a spate of mysterious sturgeon mortalities in 1994 (believed to be linked to deteriorating water quality) prompted a total ban on sturgeon harvest in the Fraser's commercial, recreational, and tribal fisheries.

Coastal British Columbia

The first Canadian record of green sturgeon was a specimen 34.3 cm TL caught in 1908 near Victoria and now in the British Columbia Provincial Museum. The largest specimen known from Canadian waters weighed approximately 350 pounds (Scott and Crossman 1973). Jordan and Evermann (1923) noted the species was "not common north of the Straits of Fuca" (cited in Halkett 1913). Although not common in Canada, occasional concentrations (possibly feeding aggregations) of green sturgeon have been encountered, particularly off the coast of Vancouver Island. There have been unauthenticated reports of green sturgeon in northern British Columbia waters as well (E. Lane, Malaspina College, Nanaimo, British Columbia, pers. comm., as cited by Houston 1988).

Sturgeon are incidentally caught by the British Columbia commercial trawl fleet, which targets primarily groundfish. Massive trawl by-catch of Fraser River green sturgeon over period of several decades appears to be linked, in part, to declines of abundance. Green sturgeon are most often thrown back, with diminished chances of survival. High densities of green sturgeon have been noted off the west coast of Vancouver Island (Carl and Clemens 1948; Clemens and Wilby 1961), such as 75 fish from 94 to 203 cm (37 to 80 inches) in length, weighing in all 952 kg (2100 pounds), taken in one day off Kyuquot Sound (Hart 1973). Trawl skippers and crew members have reported huge catches of unwanted green sturgeon off Barkley Sound, Kyuquot Sound, and Cape Cook. Trawl skippers also report dramatic declines in their green sturgeon catches over the years. Department of Fisheries and Oceans ("DFO") records do cite landings of green sturgeon at coastal shore plants, but the records are wildly inaccurate and unreliable. (Glavin 1996).

University of British Columbia student Jim Echols, who collected fisheries data on British Columbia sturgeon, says green sturgeon are declining on the coast. The trend from the 1950s to the 1970s was several tons of recorded landings per year, then nothing from 1985 to 1995. Trawler catch records in the late 1980s show hauls of as much as four tons by a single boat on a single day - during the same period, DFO records show that haul was the entirety of the catch for the entire fleet for the entire year. Echols' own observations suggested that as much as 80% of green sturgeon catches that ended up being kept and landed at shore plants did not get recorded in DFO statistics. (Glavin 1996).

Fraser River

Historically, seven foot green sturgeon were not uncommon at the mouth of the Fraser River around Sturgeon Bank (named by George Vancouver, who traded for sturgeon there from the Musqueam people in 1792). There was a small subsistence fishery for sturgeon by Native Americans prior to 1880, and trade in a crude kind of isinglass (a form of gelatin obtained from the swim bladder lining) between Natives and the Hudson Bay Company up until 1886. Almost all of the commercial catch of the British Columbia sturgeon fishery historically came from the Fraser River. The fishery, presumed to be mostly of white sturgeon, reached a peak before the turn of the century. Local markets for caviar and sturgeon flesh increased in the 1880s and export was under way by 1894. The Fraser River white sturgeon fisheries collapsed due to over-fishing, going from a peak catch of more than 1.1 million pounds in 1897 to only 35,000 pounds in 1902, when a fisheries inspector concluded that the sturgeon fishery was “practically extinct commercially.” Green sturgeon numbers in the Fraser likely declined similarly.

After 1902, sturgeon were reported to only show up occasionally as by-catch in the Lower Fraser River salmon gillnet fisheries, although incidental catch grew with the development of salmon fisheries. In the 1930s, fisherman John Slack used to pull up to half a dozen green sturgeon from each set of his gillnet at the mouth of the North Arm of the Fraser. Numbers of sturgeon grew fewer every year, and his grandson Terry Slack pulled one of the last green sturgeon out of North Arm in the summer of 1962. (Semakula and Larkin 1968; Glavin 1996)

Green sturgeon were noted to be captured occasionally in the Fraser River area in salmon gill nets by Carl and Clemens (1948), Clemens and Wilby (1961), and Fry (1973). Scott and Crossman (1973) hypothesized that sturgeon capture during the late summer and early fall in the lower Fraser indicated a migration into fresh water to spawn in the spring.

In 1985 and 1986, joint studies were conducted by Malaspina College and the British Columbia Ministry of the Environment in the Fraser River between Albrion and Chilliwack (50 to 90 km from the Fraser River mouth). Approximately 900 sturgeon were tagged in 1985 and 500 in 1986. Little attention was paid to species identification in 1985 (it was assumed that all were white sturgeon), but care was taken in 1986. Of 500 fish tagged in 1986, only two appeared “different” but were not positively identified as green sturgeon (W. T. Munro, Wildlife Branch, British Columbia Ministry of the Environment, pers. comm., as cited by Houston 1988).

In the early 1990s Terry Slack surveyed government fisheries, scientific agencies, and local fishers to see if anyone had recently seen green sturgeon in the Fraser River. The only sightings were one fish that showed up in a fisheries department test-fishery net at Maple Ridge in 1991, and a single green sturgeon caught the same year in a gillnet during the pink salmon opening at the mouth of the river, four miles off Stevenson (Glavin 1996). Green sturgeon populations in the Fraser River have collapsed to the point where they are now rarely seen (Slack and Stace-Smith 1996).

Skeena River

Green sturgeon are known to occur in the Skeena River (Scott and Crossman 1973; Houston 1988; McPhail and Carveth 1993). A few were apparently taken each year near the mouth during a salmon gill net fishery, but catches have only been reported from salt or brackish water (Houston 1988).

5. Alaska

Green sturgeon have been occasionally seen from southeast Alaska (Migdalski 1962; Morrow 1980) through the Gulf of Alaska to the northwest side of Unalaska Island in the Aleutian Chain (Wilmovsky 1954, 1964; Morrow 1980). Berg (1948) thought green sturgeon were “probably present also in the Bering Sea.” There are freshwater records from the Stikine River estuary (near Petersburg) (McPhail and Carveth 1993) and specimens from 1957 in the lower Taku River and Taku Inlet (near Juneau) (McPhail and Lindsey 1970; McPhail and Carveth 1993; UBCFC 1996). Evermann and Goldsborough (1907) also reported green sturgeon from the Copper River. No specimens are confirmed in any Alaska rivers above their estuaries.

6. Russia and Asia

The Russian and Asian records of green sturgeon should be considered as part of a distinct population from North American green sturgeon, and are properly classified as *A. mikadoi* Hilgendorf, 1892 (Birstein 1993; Birstein et al. 1993; Birstein et al. 1997; Birstein and DeSalle 1998). See the discussion on taxonomy on pages 2 and 3.

a. Russia

The green sturgeon is listed as a Category 4 species in Russia (probably endangered but with insufficient information to be classified as such). Fishing for green sturgeon is now officially forbidden in Russia (Moyle et al. 1992), but poaching is a great concern (Artyukhin and Andronov 1991). The green sturgeon is generally known in Russia as the “Sakhalin sturgeon” (Lindberg and Legeza 1965), and is called ‘sterlyad’ by Amur fishermen (Berg 1948).

Green sturgeon have been encountered in Russia in the ocean from the Bering Sea in the north (McPhail and Lindsey 1970; Miller and Lea 1972), where it was taken commercially (Magnin 1959; Magnin 1963; Scott and Crossman 1973), south through Sakhalin Island, the Tatar Strait, and the coast of the Maritime Territory. Coastal catches have been recorded in northern Russia from the Bering Sea off the coast of Kamchatka (Andriyashev and Panin 1953) and from Olyutorsky Bay in eastern coastal Kamchatka

(Reshetnikov et al. 1997). A green sturgeon was caught in 1896 near Yamsk, in the northern Sea Of Okhotsk, and in the same year an “amazing” fish over two meters long, apparently a green sturgeon, washed ashore near the mouth of the Kolpakova River, on the western coast of Kamchatka (Berg 1948). In southern Russia, catches are recorded from the southern Sea of Okhotsk (Schmidt 1950), Aniwa Bay on the southern end of Sakhalin Island (Schmidt 1904; Berg 1911), throughout the Tatar Strait (Schmidt 1904; Soldatov 1915; Berg 1948; Nikol'skii 1954; Scott and Crossman 1973), and in Peter the Great Bay, in southern coastal Maritime Territory (Soldatov and Lindberg 1930; Schmidt 1965; Scott and Crossman 1973). More than 50 green sturgeon were caught in Ussuri Bay in 1908 (Andriyashev and Panin 1953).

The green sturgeon was known to enter a number of the rivers in Maritime Territory and on Sakhalin Island, but the principal spawning streams in Russia seem to have been the Amur River (Shmidt 1904; Berg 1913; Soldatov 1915; Berg 1948; Nikol'skii 1954, 1956; Lindberg and Legeza 1965; McPhail and Lindsey 1970) and the Datta (Tumnin) River (Soldatov 1915; Soldatov and Lindberg 1930; Berg 1948; Nikol'skii 1954; Scott and Crossman 1973), draining from the northern Maritime Territory into Tatar Strait, and the lower course of the Tym' River (Nicol'skii 1954; Lindberg and Legeza 1965) of Sakhalin Island. The species has also been found rarely in Peter the Great River (Berg 1948).

Russian green sturgeon usually enter the rivers in late fall in a sexually mature condition, spending winters in the river and spawning the following summer. They apparently descend immediately to the sea following spawning (Nicol'skii 1954). Green sturgeon were apparently once rather abundant in the Datta River (Berg 1948). Spawning takes place in the Datta River from mid-June to mid-July (Berg 1948; Scott and Crossman 1973; Lindberg and Legeza 1965). Artyukhin and Andronov were told that a female green sturgeon weighing more than 80 kg and 2.5 m long was caught in June of 1985 in the Datta River. Artyukhin and Andronov (1991) caught three migrating adults in May of 1986 12-13 km up the Datta River, and six more in May and June of 1987. Replies by fishermen to questionnaires indicated the annual unrecorded catch in the lower Datta River to be as many as ten large sturgeon, taken mainly from May through mid-June. Spawned out green sturgeon are found in the river in July, and females with large eggs are caught in September. It is assumed that up to 100 green sturgeon enter the Datta River annually to spawn. Poaching is a great concern. (Artyukhin and Andronov 1991).

b. Japan

Green sturgeon were known from the Sea of Japan and the coasts of the Japanese Islands of Hokkaido and Honshu (Berg 1948; Mori 1952; Lindberg and Legeza 1965; Shmidt 1965; Ueno and Abe 1966; McPhail and Lindsey 1970; Miller and Lea 1972; Borodin et al. 1984; Moyle et al. 1992).

Otake (1907) noted three species of Japanese sturgeon; *Asipenser* (sic) *mikadoi*, Hilgendorf; *A. kikuchii*, Jordan and Snyder; and *A. guldenstadti*, Brandt. During the months of July and August young sturgeon of indeterminate species, about 4-5 cm long, and later in the season full-grown sturgeon 170 cm in length were available then in fish markets. The sturgeon were chiefly caught in the large rivers of Ishikari and Teshio of Hokkaido. Three large stuffed specimens 170-180 cm in length, with morphological similarities to *A. mikadoi* and *A. guldenstadti*, are in the College of Agriculture at Tokyo Imperial University. Okada (1955) reported spawning in the rivers (Ishikari and Teshio) of the west coast of Hokkaido in April and May (Lindberg and Legeza 1965).

Type specimens of green sturgeon (*A. mikadoi*, *A. medirostris*, and *A. medirostris mikadoi*) were collected from the Japanese island of Hokkaido by Hilgendorf in 1892; by Schmidt in 1904 at Hakodate; by Jordan and Snyder in 1906 from rivers of Hokkaido; by Berg in 1911 at Hakodate; by Snyder in 1912 at Otaru and Hakodate; and by Matsubara in 1955 at Hokkaido. Collections were also made by Lindberg in 1947 in the Sea of Japan, and by Matsubara in 1955 at Tokohu on the island of Honshu. (Lindberg and Legeza 1965).

The green sturgeon has apparently been extinct in Japan since the 1950s (K. Amaoka, pers. comm., as cited in Moyle et al. 1992). Solkolovskaya et al. (1998) classified the species as scarce to very unlikely in Japan.

c. Korea

Historically, the green sturgeon has been found along both coasts of Korea (Berg 1948; Mori 1952; Matsubara 1955; McPhail and Lindsey 1970; Morrow 1980). According to Berg (1948) it was found on the north Pacific Coast of Korea, rarely in Kunsan (on the southeast coast in the Yellow Sea), and in the Suchan River. Mori (1952) described its range as only extending south to Wonsan, on the north Pacific Coast. A type specimen of *A. mikadoi* was collected by Matsubara in 1955 at Unggi, on the very northeast coast of Korea (Lindberg and Legeza 1965). According to Lindberg and Legeza (1965), green sturgeon once entered rivers in Korea. As of the early 1990s, green sturgeon had not been reported from Korea in several decades (Pat Foley, pers. comm., as cited in Tracy 1990).

d. China & Taiwan

The green sturgeon has been found along the north Pacific Coast of China (Berg 1948) and off of Taiwan (Matsubara 1955). It is apparently considered an endangered species in China (ODFW 2000).

II. CRITERIA FOR ENDANGERED SPECIES ACT LISTING

A. THE GREEN STURGEON IS A "SPECIES" UNDER THE ESA

The ESA provides for the listing of all species warranting the protections afforded by the Act. The term "species" is defined broadly under the act to include "any subspecies of fish or wildlife or plants and any distinct population segment of any species of vertebrate fish or wildlife which interbreeds when mature." 16 U.S.C. § 1532 (16). The North American green sturgeon, *A. medirostris*, is a geographically isolated and genetically differentiated population facing a serious threat of extinction. As such, it is a "species" under the ESA and qualifies for an endangered or threatened listing to afford it the protections of the Act.

The genetic and molecular data discussed above indicates that the North American and Asian forms of the green sturgeon are two distinct and valid species, *A. medirostris* and *A. mikadoi*, respectively. However, even if the North American and Asian forms of the green sturgeon were determined to be conspecific, the North American form is a geographically isolated distinct population segment which meets the criteria of the definition of a "species" under the ESA, with no evidence of interchange or overlap between the two forms. Additionally, the Russian and Asian forms are largely endangered or extinct throughout their former range. The green sturgeon meets the definition of a species which is endangered or threatened "throughout all or a significant portion of its range." 16 U. S. C. §1532(6) and §1532(20).

B. THE GREEN STURGEON IS ENDANGERED OR THREATENED UNDER THE ESA

NMFS is required to determine, based solely on the best scientific and commercial data available, whether a species is endangered or threatened because of any of the following factors: (1) the present or threatened destruction, modification, or curtailment of its habitat or range; (2) overutilization for commercial, recreational, scientific, or educational purposes; (3) disease or predation; (4) the inadequacy of existing regulatory mechanisms; or (5) other natural or manmade factors affecting its continued existence.

16 U.S.C. §1533(a)(1) and 1533(b). Petitioners believe that all of these factors except possibly disease and predation have played a role in bringing the green sturgeon to its current perilous condition. However, depensatory²⁷ mortality factors may be operating on green sturgeon at their small population sizes.

Green sturgeon are adapted to large mainstem river systems with diverse, dynamic habitats, featuring large seasonal and annual variations in physical conditions and resource availability (Sheehan and Rasmussen 1993). Before large scale water development projects, natural seasonal cycles in weather and runoff drove changes in water velocity, temperature, substrate, and turbidity, and periodic floods and droughts would radically alter the riverine environment. Populations of green sturgeon were historically buffered from annual variation in environmental conditions by their mobility, opportunistic food habits, delayed maturation, large size, longevity, and high individual fecundity.

Delayed maturation speeds growth to large sizes as energy is devoted to somatic rather than gonadal development. Large size helps reduce predation, lowering natural mortality rates and increasing longevity. A long life span allows fish numerous opportunities to spawn and reduces the need to spawn in years when conditions are not suitable. Many species have been observed to reabsorb eggs under these conditions (Artyukhin et al. 1979; Chapman 1989). The high fecundity of green sturgeon associated with their large size improves spawning success in years when conditions are favorable.

Unfortunately, some of these very adaptations have made green sturgeon especially vulnerable to over-fishing and other anthropogenic factors. Availability of food and critical spawning areas have been limited by the construction of dams. Dam and reservoir operation for hydro power generation, flood control, irrigation, and navigation reduces the seasonal and annual variability in flows needed to provide suitable spawning and rearing conditions for sturgeon and many of their prey. Alterations to river systems have favored the development of a new array of prey, predators, and competitors. Benthic feeding habits and delayed maturation increase the vulnerability of green sturgeon to bioaccumulation of toxic pollutants. Longevity and delayed maturation make green sturgeon extremely susceptible to overexploitation by fisheries (since the larger fish of breeding age are mined out of the population), and their large size increases the incentives for excessive or illegal harvest. (Beamesderfer and Farr 1997).

Moyle (1994) listed the factors contributing to the decline of green sturgeon (in order of impact) as

²⁷

Depensatory = a higher percentage of progressively smaller populations is taken by mortality factors, primarily disease, parasites, and predation.

over-fishing; watershed degradation (encompassing the effects of logging, road construction, overgrazing, and urbanization); water diversions; negative effects of increased variability in precipitation; pollution; ocean conditions; and other factors (including altered food supply).

1. Present or Threatened Destruction, Modification, or Curtailment of Its Habitat or Range

A recent American Fisheries Society assessment of marine fish stocks (Musick et al. 2000) concluded that the green sturgeon has suffered an 88% decline in most of its range. Twice as many green sturgeon spawning populations have been extirpated in the last century as are known to currently remain. Spawning runs have disappeared from the San Joaquin, Eel, and South Fork Trinity Rivers, probably the Umpqua River, and possibly the Fraser River as well. Spawning is currently known to occur only in the Sacramento and Klamath/Trinity Rivers, and possibly the Rogue River. Although historic data is lacking, it is clear from anecdotal accounts and reports from fishers that green sturgeon have experienced a severe recent decline in overall abundance. Although much of the loss and degradation of sturgeon spawning habitat is attributable to historic land use practices, habitat alteration and water projects which jeopardize the continued existence of the green sturgeon continue today.

Historical logging practices such as splash dams and widespread removal of log jams and snags from river channels have destroyed many deep holes which once occurred in the large river systems of the Pacific Northwest (Bottom et al. 1985). These activities not only degraded salmonid habitat, but also adversely modified habitat for sturgeon. The negative impacts of poor land use practices associated with timber harvest, agriculture (including overgrazing by cattle), mining, road construction, and urban development on salmonid habitat in the Pacific Northwest are well documented (NMFS 1996). Many of these activities degrade the quality of habitat for green sturgeon (loss of pool habitat and suitable substrate, increased sediment input, higher water temperatures) as well.

As far back as the late 1800s, the Army Corps of Engineers sent “snag boats” out to break up log jams and remove woody debris on numerous rivers, including the Sacramento, Russian, Eel, and Willamette Rivers, to make them navigable to boat traffic. Records show that in just one decade starting in 1898, 30,000 snags were removed from the lower Skagit River in Washington alone (Chui 1999).

The elimination of deep holes used by sturgeon in the Eel River was typical of the era. In the early 1900s the Eel had numerous big, deep holes with cold water in summer, where large sturgeon were seen and caught. When the railroad was built along the river, dirt was simply bulldozed over the bank into the river, filling in many big holes, especially in the lower river. Existing landslides in the Eel River canyon started moving when the railroad was built. The railroad also dynamited a falls near Kikawaka and blew out big rocks that formed a toe on the Kikawaka slide. By time the railroad was completed in 1914, a tremendous amount of material had been pushed and blown into the river. The river filled in to the point where ships could no longer run up river as far as Scotia, as they once had. (Mathison 1998).

Poor land use practices in the past continue to add excessive sediment to river systems used by green sturgeon. Several decades of clear-cut logging contributed to massive erosion and sedimentation of many Pacific Northwest river systems when the floods of 1964 arrived. The documented disappearance of green sturgeon from the South Fork Trinity River after the 1964 flood indicates the scale of the changes in river morphology which occurred. On the Eel River, many of the remaining big rocks were blown out of the river when the railroad was built back after the 1964 flood (Mathison 1998). The holes that are left now are one-third their original size. Mathison (1998) has a picture of one large hole on the Eel taken in 1913, when it had three big rocks - now it has none.

Construction of dams has had a huge impact on sturgeon habitat. Numerous large dams have blocked access to previously productive sturgeon habitat. These dams continue to impact sturgeon habitat downstream by modifying the natural flow regimes of rivers. These dams include Shasta, Keswick, and Red Bluff Diversion Dam on the Sacramento River and Oroville Dam on the Feather River; Friant Dam on the San Joaquin River; Scott Dam on the Eel River; Iron Gate Dam on the Klamath River and Lewiston Dam on

the Trinity River; Lost Creek Dam on the Rogue River; and Bonneville and other dams on the Columbia River. All of these dams have blocked salmonid migration to productive spawning and rearing habitat. Because green sturgeon have not been as well studied as salmonids, it is unknown if they once spawned or reared above any of these large dams, but it is highly likely that they did.

Columbia River white sturgeon populations decreased dramatically after the major dams on the river were built (Semakula and Larkin 1968; Galbreath 1985; Lane 1991), and it was only by an accident of location that Bonneville Dam did not completely eradicate the white sturgeon population in the lower Columbia River.²⁸

Presumably, green sturgeon have a specific set of flow, depth, and substrate requirements for spawning and then for the early life stage histories of their young. The flows and channel of the Sacramento and other rivers have been highly modified, so it is likely that suitable conditions for spawning and rearing of green sturgeon occur less frequently now than they once did (pre-1940s), especially during or after periods of extended drought (USFWS 1995). After Van Arsdale Dam was built and water diversions into the Russian River began, a few dry years in the 1930s had a devastating impact on fish populations in the Eel River. Salmon (and presumably sturgeon) congregated in the lower part of the river, ran out of oxygen due to low water, and died by the thousands (Mathison 1998).

The modification of natural flow regimes below large dams has altered the sediment transport characteristics of rivers, increased water temperatures, and changed fish community structure. Water withdrawal, conveyance, and storage has drastically altered natural hydrological cycles. Diversion and transfer of water has depleted river flows necessary for migration, spawning, rearing, and flushing of sediment from spawning substrates (NMFS 1996). The reproductive potential of green sturgeon is greatly affected by the availability of spawning habitat (Detlaff et al. 1993).

There is great concern about the health of the Klamath basin ecosystem. Many species of Klamath River fish (including eulachon, lamprey, steelhead, coho salmon, and chinook salmon) have declined dramatically over the past few decades, primarily due to loss or degradation of fresh water habitat (Van Eenennaam et al. 2001).

As flow has become highly manipulated in the Sacramento-San Joaquin Delta, a broad scope of direct and indirect impacts have diminished salmonid survival. These impacts may also be affecting sturgeon survival in the Delta. The problems are primarily related to changes in hydrology, whereby the timing, quantity, export and distribution of water flow into and through the Delta have been altered. The primary factors causing salmonid mortality in the Delta are considered to be: 1) the diversion of fish from the main stem Sacramento River into the central and south Delta where environmental conditions are poor; 2) reverse flow conditions created by pumping; and 3) entrainment at CVP and SWP pumping plants and associated problems in Clifton Court Forebay (NMFS 1997).

The rivers in the Sacramento-San Joaquin systems are regulated to the point that high flows below the dams typically occur in late spring and summer (during the irrigation season), and low flows occur in the fall, winter, and early spring during the storage season (Reynolds et al. 1993). This flow regime is completely inverse to conditions in which green sturgeon evolved in the system. According to USFWS (1995), the major factors affecting the abundance of native non-salmonid anadromous fish in the Central Valley include: inadequate stream flows and temperatures in the Sacramento and San Joaquin Rivers, water export/inadequate outflows in the Delta, entrainment losses at water diversions, lack of abundant food, poor water quality, predation by and competition from introduced species, and lack of suitable spawning and rearing habitat (USFWS 1995).

28

The most productive white sturgeon spawning habitat is just downstream of Bonneville Dam. If the dam had been constructed further downstream in the gorge, white sturgeon would have been eliminated from the lower part of the system.

Juvenile habitat for sturgeon in the Delta is known to be degraded by low freshwater flows and high water diversion rates during the spawning and nursery periods (Kohlhorst 1980). Low freshwater flows apparently impact juveniles by restricting the available habitat or reducing food supplies. Water pumping in the Sacramento-San Joaquin Delta affects the oxygen and temperature conditions necessary to maintain food organisms, particularly *Neomysis* and *Corophium* populations in the Delta for young of year sturgeon. Water diversions also reduce survival by directly moving fish or by changing flow patterns in a way that disrupts migrations. It is unknown what flows are critical for moving sturgeon through the Delta, although naturally produced high winter and spring flows are likely important for moving juveniles out of the system.

State and Federal water pumping from the Delta has been steadily increasing. The average water withdrawal from the Delta was 0.73 million acre feet (maf) per year in the 1950s, 1.70 maf in the 1960s, 3.64 maf in the 1970s, 4.99 maf in the 1980s, and 4.53 maf in the 1990s. 6.30 maf of water was withdrawn from the Delta in 2000 (DWR 2001). When inflows to the Delta are low, pumping can completely change Delta hydraulics, causing net flows toward the pumps. Entrainment of juvenile sturgeon in pumping facilities is a major concern (see the section on page 50 on entrainment). Sturgeon migration, rearing, and feeding will potentially be increasingly disrupted and more entrainment will occur as water exports increase (Kohlhorst 1980).

2. Overutilization For Commercial, Recreational, Scientific, or Educational Purposes

a. Fisheries

The green sturgeon has generally been held in lower esteem by fishers than the white sturgeon. It has a reputation as a poor food fish,²⁹ it is much less abundant and smaller in size than white sturgeon, and it spends less time in fresh water or estuaries, thereby being harder to catch. In the past, it was rarely targeted as a commercial or sport fish but was caught incidental to catches of white sturgeon, or as by-catch in fisheries targeting salmon and bottomfish. This is still largely true today, but concentrations of green sturgeon are targeted by commercial gill net fishers in Washington and Oregon and a fairly intense tribal fishery for spawning or spawned out fish has developed on the Klamath River. Green sturgeon have become more popular in the last decade as populations of other sport fish have declined and as more effective fishing techniques have been developed. Fisheries for green sturgeon exist mainly in these areas: the Columbia River, Willapa Bay, Grays Harbor, the Klamath and Trinity Rivers, and the Sacramento-San Joaquin estuary. (Moyle et al. 1995).

Exploitation of green sturgeon in the various commercial, sport, tribal, and illegal fisheries appears to have been excessive for many years. These fisheries likely all depend largely upon sturgeon from California. Of particular concern are the Columbia River, Willapa Bay, and Grays Harbor fisheries, as no spawning adults have been documented in the region and the average size of green sturgeon caught there has been declining steadily (USFWS 1995). Sturgeon fisheries have likely been “mining” a stock of large, old fish that has probably not been able to renew itself to keep up with harvest rates. The example of the collapse of the Columbia River white sturgeon commercial fishery shows how vulnerable sturgeon populations are to over-fishing. Commercial fishing for white sturgeon on the Columbia only started in 1880, had peaked by 1897, and was followed by a sharp decline (93.3% reduction in catch from 1897 to

²⁹

Jordon and Evermann (1923) expressed a common attitude towards the green sturgeon: “As a food-fish, it is of very inferior rank; indeed, it is commonly believed to be poisonous, but this belief is without warrant. Its flesh, however, is dark, has a strong, disagreeable taste, and an unpleasant odor, and is regarded as inferior to that of the white sturgeon.” Even the roe of green sturgeon has been rejected as unfit for caviar. The bad culinary reputation of green sturgeon probably stems mostly from the dark color of the flesh. Properly prepared (smoked and canned, then allowed to “age” for several months) it is reported to be quite tasty (Moyle et al. 1995; S. Wright, pers. comm. 2001).

1905) to practically commercial extinction.³⁰

Compilation of data shows that a minimum of 6,000 to 11,000 green sturgeon were being harvested by the various fisheries each year until recently (Moyle et al. 1992). King (2001) conservatively estimated an average of 4,216 green sturgeon have been harvested each year since 1985 by the various west coast fisheries. This figure is likely an underestimate, and excludes Canadian catch, illegal harvest, under-reported sport and tribal harvest, and non-reported ocean trawl catch and discarded fish.

Ricker (1975) concluded that an annual harvest rate of 5% or more on a population consisting of 12 to 15 age groups or more may eventually cause a major reduction in total biomass and in relative biomass of older individuals. The effects become more pronounced as the number of age classes in a population increases. At current harvest rates, the total green sturgeon population would have to number considerably greater than 84,320, and at recent harvest levels, as many as 220,000 individuals to escape over-harvest as defined by Ricker (1975). There are certainly no population estimates of green sturgeon which approximate these numbers or which justify recent levels of harvest by various fisheries.

Sustainable harvest levels cannot be determined until the stock structure of green sturgeon is understood. Each river system may prove to have different green sturgeon populations that may or may not interbreed. For populations harvested by in-river fisheries, such as the tribal harvest on the Klamath River, the older and highly fecund females are impacted the most by the annual harvests. Male fish compose the majority of the run, with females generally larger and older than males. The number of females of breeding age or eggs produced in a population would be the only reliable criteria of population stability.

There have been attempts to reduce the threat of over-fishing by the elimination of the targeted commercial fisheries in Washington and the Columbia River, and implementation of more restrictive size limits for sport fisheries. The history of these size limits, and the inadequacy of size limit reductions in protecting the species are discussed on page 48 in the section on the inadequacy of existing regulatory mechanisms. Green sturgeon are still a legal sport fish in California, Oregon, and Washington, although there has been a moratorium placed on sport fishing in northern coastal California, including the Klamath River. However, legal size limits directed at white sturgeon populations do not protect the majority of the green sturgeon breeding population, as they are mostly smaller than 183 cm.

Green sturgeon along the entire Pacific Coast are monitored on a regional basis with no understanding of their population structure. This is a serious concern, because fishery management depends on accurate stock assessments to determine the status of populations, accurate monitoring of harvest levels, and a known broodstock population of large mature female sturgeon. All these factors remain unknown for green sturgeon, which are less abundant than white sturgeon. Over-harvest coupled with reduced habitat quality can be a lethal combination for a sturgeon population (Beamesderfer 1997). In addition, managers have no idea as to whether or not compensatory mortality factors might manifest themselves at low population sizes. Unfortunately, these can only be identified as a possible cause after a population becomes extinct. However, the documented loss of spawning populations in specific rivers, such as the South Fork Trinity, Eel, and San Joaquin Rivers, should have been an early warning sign to the objective observer.

i. San Francisco Bay System

The historic commercial sturgeon fishery in San Francisco Bay collapsed from over-fishing in a

³⁰

White sturgeon populations in the Columbia River remained depressed for 80 years after the collapse of the late 1800s. Recovery followed protection of sturgeon larger than 6 feet, which provided for a pool of sturgeon broodstock. Recovery was possible only because incidental harvest rates were low in the commercial gill net and salmon sport fisheries. White sturgeon fisheries expanded again in the 1980s as fishers switched from declining salmon fisheries. Harvest restrictions were tightened in time to protect white sturgeon populations in the lower river, but not in mainstem reservoirs on the Columbia.

manner similar to the Columbia River fishery. 718,000 pounds of sturgeon (presumed to be mostly white sturgeon³¹) were landed in the Bay in 1892, and 1.7 million pounds in 1885, the largest catch on record. The annual catch from 1875 to 1892 averaged just under 500,000 pounds, and from 1892 to 1901 was between 100,000 and 200,000 pounds. The fishery was shut down between 1901 and 1910, when white sturgeon were claimed to be on verge of extinction, reopened for two years, then closed again until 1916 (Skinner 1962). The commercial sturgeon fishery was finally abolished by the state legislature in 1917, and remained closed until 1954. In 1954 a restricted sport fishery for sturgeon was opened up, but fishermen did not figure out how to effectively catch them until 1964, when use of grass shrimp as bait began. Because of fears of over-fishing, a 117-183 mm slot limit was opened in 1991.

There is no present commercial fishery, and green sturgeon in San Francisco Bay are caught primarily by sport fishers who are angling for white sturgeon. No numbers are kept of sport catches of green sturgeon in the San Francisco Bay system. Assuming that legal size green sturgeon are harvested in proportion to their numbers relative to white sturgeon and at the same rate, then exploitation rates have been gradually increasing since 1954 (Kohlhorst et al. 1991). Annual harvest rates for white sturgeon in the early 1990s were calculated at 8 to 11.5% per year, which is regarded as excessive for such a long-lived species that seems to depend on strong year classes produced during years of exceptionally high outflow. A rough estimated harvest rate of legal size green sturgeon can be determined based on CDFG estimates of abundance in the system during the 1990s,³² an assumed harvest rate of 8 to 11.5% would remove 53 to 78 fish annually.

CDFG recommended that the minimum size limit for white sturgeon be raised to allow more females to mature, as female white sturgeon mature at larger sizes than males. The regulatory action taken for white sturgeon has been to increase the minimum harvest size to 117 cm (46 inches) in 5 cm (2 inch) increments, and to impose a 183 cm (72 inch) maximum size limit (USFWS 1995). These regulations also apply to green sturgeon, but are less protective of them because green sturgeon are smaller than white sturgeon, and the 183 cm TL maximum size limit allows many of the larger female green sturgeon to be harvested. It is estimated that the majority of the largest and oldest green sturgeon fall within the permitted size range for harvest (USFWS 1995).

ii. Klamath-Trinity River System

The second largest fishery for green sturgeon (after the lower Columbia River and Washington coastal fisheries, discussed on pages 43-45) is in the Klamath and Trinity rivers. A small number of green sturgeon are probably taken in the sport fishery, but the main harvest is by a tribal gill net fishery³³. This fishery targets green sturgeon as they move up the river to spawn during the spring and again as fish return seaward through the estuary during June-August (USFWS 1990). Mainly adult sturgeon (less than 130 cm FL) are captured (mean length 179 cm in 1988), although some juveniles are caught in the estuary during the fall chinook salmon net fishery.³⁴

Data on the gill net fishery exists only since 1980 and the available harvest estimates (USFWS 1989) are biased low by variable and inconsistent sampling effort based on volunteered data. Also, some harvest occurs prior to the annual monitoring activities of the USFWS, and the USFWS monitors only the harvest on the Yurok Indian Reservation. Catch estimates by Hoopa tribal fishers averaged 16 fish per year from 1985-1999 (King 2001), and catches by Karuk tribal fishers are undetermined (USFWS 1995). In the Yurok Fishery, an average of 84% of adult green sturgeon were caught during the spring fishery (April to July)

³¹ Most early fishery accounts referred to white sturgeon, as green sturgeon were considered inferior. Although the fishery was aimed at white sturgeon, greens were apparently killed because their sharp scutes ripped up the gill nets.

³² Based on green sturgeon population estimates provided by Dave Kohlhorst, CDFG. See page 12 for an explanation of these population estimates.

³³ The Yurok tribe has been harvesting green sturgeon for more than a thousand years, and the fishery is an integral part of the tribe's subsistence, culture, and economy. The Yurok use the sturgeon meat and eggs for food, and process other parts of the fish to make glue (Van Eenennaam et al. 2001)

³⁴ Juveniles averaged 7 % of the catch before 1985 - an estimated 188 immature fish were taken from 1981 to 1984. The abundance of immature green sturgeon peaks in the Klamath estuary from July-September, with most of these fish believed to be coastal migrants (USFWS 1984, 1985).

from 1980 to 1995. Most sturgeon caught in August or later were down-stream migrant post-spawners (Nakamoto et al. 1995).

With that in mind, the estimated harvest for the Klamath system averaged 375 adult fish per year from 1980 to 1999 (USFWS 1989, 1990; King 2001). See Appendix 2 on page 57 for complete Klamath River catch data. There seems to be some indication of decline, with the average annual catch during the 1980s being 483 fish, whereas during the 1990s it was only 267 fish (USFWS 1989, 1990; King 2001). This fishery is a relatively recent development and will likely expand as increased restrictions are placed on the harvest of depleted salmon populations in the rivers, thus increasing the likelihood for future green sturgeon declines (Moyle et al. 1992; USFWS 1995).

The extent of the legal hook and line fishery for sturgeon in the Klamath basin is unknown, depending on data from voluntary contacts with relatively few native fishers (USFWS 1993). A significant illegal snag harvest once occurred at "Coon Creek Falls," where a debris slide created a migration obstacle in 1977 at river km 58. At least 400 green sturgeon were illegally snagged there in 1980. This obstruction was blasted in 1981, which alleviated the problem somewhat, but fish continued to back up. Seventy green sturgeon were illegally snagged at this location in 1981, 50 fish in 1982, and unknown numbers, but continued snagging in 1983. It is unknown how much illegal snagging of green sturgeon has occurred in recent years. The legal sport catch of green sturgeon on the Klamath River is unknown, but presumed to be relatively few fish (King 2001).

iii. Oregon Coastal Areas

ODFW estimated a sport catch of 196 green sturgeon per year in Oregon river estuaries and bays from 1985-1989 (ODFW 2000a). From 1990 to 1999, the average Oregon coastal sport catch was 191 fish (King 1998, 2001). See Appendix 1 on page 56 for complete sport catch statistics. The Oregon coastal trawl catch is discussed below.

iv. Columbia River

A significant amount of green sturgeon harvest occurs in the Columbia River region - they are commercially caught with white sturgeon in the Columbia River estuary and are often captured during gill netting for salmon in the estuary. There is no evidence of green sturgeon spawning in the rivers of this region, and it is likely that the fish harvested here migrated from Oregon or California, as indicated by limited recaptures of tagged sturgeon. Further evidence of the lack of local recruitment into the fishery is that few juvenile sturgeon (less than 1.3 m) are caught. (Emmett et al. 1991).

There have been some notably high catches, such as about 6,000 green sturgeon harvested in the Columbia River estuary alone during a four-day sturgeon fishing season in 1986 (Emmett et al. 1991), and 4900 fish taken in 1987. These large catches occurred in a directed gill net fishery, which has since been banned (USFWS 1995). The commercial catch averaged 3,500 fish from 1985-1989, 2,002 fish from 1990-1994, and 974 fish from 1995-1999 (ODFW data provided by Steve King, 2001).

The Columbia River sport fishery catch averaged 279 green sturgeon from 1985-1989. From 1990-1994 the average was 66 fish, and from 1995-1999 the average was at least 58 fish³⁵ (King 2001). Brix (2000) estimated that in recent years, the sport fishery has recorded landings of an average of 52 fish per year.³⁶ Far more white sturgeon are caught by sport fishers in this region; only 13-21 green sturgeon (as compared to 25,517 white sturgeon) were reported from the

³⁵ Although ODFW data indicates a sport catch of only 21 green sturgeon in the Columbia River in 1995 and 63 fish in 1996, expanded green sturgeon catch data provided by Steve King, ODFW for 1995 and 1996 (the only years the expanded catch data is available for) indicates the number of green sturgeon caught in the Columbia basin to be 318 and 415 fish, respectively.

³⁶ Estimates available only from 1988 through 1997.

Columbia River system in 1995 sport fishing surveys by the Washington Department of Fish and Wildlife (WDFW 1995).

v. Washington Coastal Areas

A significant amount of green sturgeon harvest occurs in Grays Harbor and Willapa Bay, Washington, to the immediate north of the Columbia River estuary.

The recorded combined commercial catch³⁷ of green sturgeon in Willapa Bay and Grays Harbor shows some decline from the peak catches that occurred from 1969 to 1971 (an average of 4765 fish per year), even before the banning of the directed gill net fishery. An annual average of 1,374 green sturgeon were landed in the 1950s (1953-1959), 3038 fish in the 1960s, 2565 fish in the 1970s, and 1691 fish in the 1980s (Brix 2000).

The 1990-1993 annual average was 1689 fish, comparable to the 1980s, but the 1994-1999 annual average was only 323 fish (however, according to Beamesderfer (1997), about 1000 green sturgeon were caught on average from 1993-1997 in the lower river commercial drift gill net fishery). There has not been an early gillnet season (July to mid-August) from 1994 to present, potentially reducing green sturgeon catches somewhat, primarily in Willapa Bay (Brix 2000). The maximum size for green sturgeon was also reduced from 72 inches to 66 inches in 1993. In 1998 and 1999 only 90 and 23 green sturgeon were landed, respectively, in the combined commercial catches according to King (2001), with tribal and sport fishers taking at least another 150 fish. Although the targeted green sturgeon fishery has been halted, considerable numbers of green sturgeon are still taken incidentally in the salmon gillnet fishery in the lower river (ODFW 1991). Another disturbing trend is that green sturgeon caught in the commercial fishery have declined in size over the years. In the 1960s, mean size of green sturgeon landed ranged between 17 and 19 kg (37-42 pounds), while since 1980, mean weight has usually been between 12 and 14 kg (26-31 pounds) (USFWS 1995).

Willapa Bay

The green sturgeon is the primary bottom fish landed in Willapa Bay (Emmett et al. 1991). Up until recent years an average of 15.9 tons of green sturgeon (equivalent to about 2,000-4,000 fish) have been harvested each year in Willapa Bay (Emmett et al. 1991). The average annual commercial catch in Willapa Bay during the 1970s was 2,044 fish, during the 1980s was 1,043 fish, and during the 1990s was 377 fish. (King 2001). An annual average of 9 green sturgeon have been caught by sport fishers in Willapa Bay since 1985 (King 2001).

Grays Harbor

Up until recent years an average of 4.7 tons of green sturgeon (equivalent to about 500-1,000 fish) have been harvested each year in Grays Harbor (Emmett et al. 1991). The average annual commercial catch in Grays Harbor during the 1970s was 521 fish, during the 1980s was 645 fish, and during the 1990s was 431 fish (King 2001). Green sturgeon are harvested in an tribal gill net fishery in Grays Harbor - the commercial treaty catch since 1985 has averaged 42-47 fish per year (Brix 2000; King 2001). An annual average of 42 green sturgeon have been caught by sport fishers in Grays Harbor/Chehalis River since 1985 (King 2001).

vi. Ocean Trawl Fisheries

³⁷

Landings before 1984 based on total poundage divided by the 1985-1991 average lower Columbia white sturgeon sampled weight of 32.9 pounds/fish. Catch data since 1985 includes commercial treaty catch from Grays Harbor, which averaged 42 fish per year. Landings include set-line landings (less than 25 per year) which were prohibited as of June 1990.

Data on the incidental catch of green sturgeon in the Oregon coastal and Washington ocean trawl fisheries are a better index of the relative abundance of the species than data from sturgeon-directed fisheries, since green sturgeon are not targeted by these fisheries (Wright 2000). Records of combined Washington and Oregon trawl landings of green sturgeon show a recent decline. An annual average of 16,056 pounds (approximately 443 fish) was recorded from 1981-1989.³⁸ An annual average of only 6,244 pounds (approximately 186 fish) were caught from 1990-1999.³⁹ The 1999 trawl fishery caught only 929 pounds (equivalent to 24 fish).⁴⁰ (ODFW 2000).

Oregon coastal trawl catches declined from an annual average of 274 green sturgeon from 1985-1989, to 176 fish from 1990-1994, to 142 fish from 1995-1999. The Washington ocean trawl catches similarly plummeted from an annual average of 142 green sturgeon from 1985-1989, to 16 fish from 1990-1994, to only 2 fish from 1995-1999. (King 2001).

Apparently no data is kept on ocean trawl catches of green sturgeon in California, including incidental catches in the California commercial trawl fishery (Dave Kohlhorst, Sacramento CDFG, and Rick Klingbale, Monterey CDFG, pers. comm., 2001).

The Pacific Fisheries Information Network (PacFIN) has records since 1990 of commercial landings of green sturgeon by state, port, and gear type. These numbers reflect only what was reported to PacFIN by the states – landings within state-managed inland and marine waters may not be reflected. The majority of the landings were from trawl catches. California apparently does not report data to PacFIN. An annual average of 2.67 metric tons (mts) of green sturgeon were landed in Oregon ports from 1990-1994, and an average of 0.83 mts landed in Washington ports during the same period. From 1995-2000 (no records were available for 1997) an annual average of 1.00 mts were landed in Oregon ports, and only 0.03 mts in Washington ports (PacFIN 2001).

vii. Canadian Fisheries

Historic Fraser River white sturgeon fisheries are documented to have collapsed in a manner similar to the Columbia river fishery, going from a peak catch of more than 1.1 million pounds in 1897 to only 35,000 pounds in 1902. Green sturgeon numbers in the Fraser system likely declined sharply. After 1902, sturgeon were reported to only show up occasionally as by-catch in the Lower Fraser River salmon gillnet fisheries, although incidental catch grew with the development of salmon fisheries. Between 1941 and 1951, catches averaged about 200-500 fish per year according to Houston (1988). Steep declines in green sturgeon abundance were noted in the middle 20th century.

As discussed on page 29 in the section on Canadian distribution and abundance, a total ban on sturgeon harvest in the Fraser's commercial, recreation, and tribal fisheries was instituted in 1994. Massive by-catch of sturgeon by the British Columbia commercial trawl fleet over a period of several decades appears to be linked, in part, to declines in abundance of Fraser River green sturgeon. Several tons of green sturgeon landings per year were recorded from the 1950s to the 1970s, then nothing from 1985 to 1995. Trawl skippers have reported huge catches of unwanted green sturgeon (such as 75 fish weighing in all 2100 pounds (952 kg) taken in one day off Kyuquot Sound, and hauls of as much as four tons by a single boat on a single day in the late 1980s), followed by dramatic declines in their green sturgeon catches over the years. Department of Fisheries and Oceans (DFO) records of green sturgeon landings are considered unreliable, with as much as 80% of green sturgeon catches not being recorded in DFO statistics. (Glavin 1996). More recent data on green sturgeon by-catch was unavailable from DFO.

³⁸ Estimate made from average weight of green sturgeon from 1991 Lower Columbia River fishery, 32.6 lbs.

³⁹ The 1997 average weight for green sturgeon landed in Oregon was 36.3 lbs. The maximum size limit for green sturgeon landed in ocean trawl fisheries was decreased from 72" to 66" in 1998. 1998 Columbia River gill net average weight for the same size fish was 35.5 lbs. for green sturgeon.

⁴⁰ 1998 Columbia River gill net average weight for the same size fish was 39.5 lbs. for green sturgeon.

3. Disease and Predation

Disease and predation are currently not known to be major factors in the decline of green sturgeon. However, as discussed on page 10, disease and predation may operate as compensatory mortality factors on small populations.

4. Inadequacy of Existing Regulatory Mechanisms

Overview of Existing Regulatory Mechanisms

The green sturgeon currently has no federal status or protection as a protected species. It is considered a federal Species of Concern (formerly USFWS Category C-2), but this offers no regulatory or conservation benefits to the species, nor protection under the ESA. It is currently considered a species of special concern in California, but it is not a state threatened or endangered species and receives no protection under the California Endangered Species Act. It enjoys no special state protection status in Oregon, Washington, or Alaska. Green sturgeon were given “rare” status in Canada in 1987.

Existing regulatory mechanisms that could potentially provide some protection for the green sturgeon include: (1) consideration under the California Environmental Quality Act (“CEQA”) and the National Environmental Policy Act (“NEPA”); (2) consideration under section 404 of the Clean Water Act (“CWA”); (3) co-occurrence with other species protected by the Endangered Species Act (“ESA”); (4) ecosystem restoration projects planned for salmonid restoration in rivers used by green sturgeon for spawning; and (5) harvest regulations which protect a sufficient stock of mature fish of breeding age.

Both NEPA and CEQA require a full public disclosure of the potential environmental impacts of proposed projects. The public agency with primary authority or jurisdiction over the project is designated as the lead agency and is responsible for conducting a review of the project and consulting with other agencies concerned with resources affected by the project. Section 15065 of the CEQA guidelines require a finding of significance if a project has the potential to “reduce the number or restrict the range of a rare or endangered plant or animal.” Species that are eligible for listing as rare, threatened, or endangered but are not so listed are given the same protection as those species that are officially listed with the State.

Once significant impacts are identified, the lead agency has the option to require mitigation for effects through changes in the project, or to decide that overriding considerations make mitigation infeasible. In the latter case, projects may be approved that cause significant environmental damage, such as destruction of sensitive species. Protection of listed species through CEQA is therefore at the discretion of the lead agency involved. CEQA provides that when overriding social and economic considerations can be demonstrated, project proposals may go forward, even in cases where the continued existence of the species may be threatened, or where adverse impacts are not mitigated to the point of insignificance. NEPA lacks even the minimal substantive provisions of CEQA.

Aside from the ESA, the primary Federal law that potentially affords some protection for the green sturgeon is section 404 of the CWA. The CWA may provide some general protections for the habitat of the species. However, the CWA has proved inadequate to protect nearly all the salmonid species which overlap the range of the green sturgeon, are declining precipitously, and are now listed under the ESA.

The perilous status of the green sturgeon reflects the overall failure or inability of existing CEQA, NEPA, and other Federal, State, and local ordinances and statutes to protect and provide for the conservation of the green sturgeon.

Harvest Regulations

Various size limit restrictions on the commercial and sport harvest of sturgeon have been implemented in California, Oregon, and Washington, in response to over-harvest, or “mining” of large mature fish of breeding age. These regulations have been aimed mostly at white sturgeon, but also apply

to green sturgeon. However, they are less protective of green sturgeon, since the largest green sturgeon of breeding age tend to still fall within the maximum size limit.

The evolution of the Columbia River, Willapa Bay, and Grays Harbor commercial regulations for green sturgeon are as follows: from 1989-1992 the commercial fishery was required to release white sturgeon from July until August 1, but green sturgeon retention was allowed. In 1993 the commercial maximum size limit was changed from 72 to 66 inches, retaining a 48 inch minimum. There was not an early gillnet season (July to mid-August) from 1994 to 1999, potentially reducing green sturgeon catches somewhat, primarily in Willapa Bay. However, a three day, late-August 2000 fishery in Grays Harbor targeted both chinook salmon and green sturgeon, taking over 500 green sturgeon (S. Wright, pers. comm. 2001).

In October 1996, ODFW and WDFW signed the Olympia Accord on Columbia River Sturgeon Fishery Management. Green sturgeon-only commercial seasons were disallowed, but green sturgeon can be taken concurrently during white sturgeon seasons “provided the green sturgeon catch rate does not exceed harvest rates observed in the past.” ODFW and WDFW failed to note that a sustainable harvest rate can only be calculated if the total population size is known. No seasonal quota was established for green sturgeon, and the Columbia River white sturgeon commercial fishery is managed for an annual quota of 13,450 white sturgeon! This accord did not offer much protection to green sturgeon, given that past harvests have included some alarmingly high catches (such as the 6,000 fish harvested in the Columbia River in four days in 1986). (Brix 2000).

In 1997 the commercial maximum in the Columbia River was reduced to 60 inches, but for white sturgeon only, a definite indication that there was less concern for fish produced in someone else’s jurisdiction. Since 1997 the commercial fishing opportunity for green sturgeon has been reduced somewhat, as there is no more targeted fishery (except as noted above in August 2000) and they have been allowed as incidental catch in salmon seasons only. The recreational regulations for green sturgeon are the same as for white sturgeon. The minimum size limit for the Columbia River/Willapa Bay sport fishery was increased in 1989 to 40 inches, and again in 1994 to 42 inches, with a 66 inch maximum. (Brix 2000).

Currently, there is no active management of the green sturgeon population in the Sacramento-San Joaquin estuary, beyond what is deemed necessary to protect the white sturgeon fishery. However, the California Fish and Game Commission in 1993 banned fishing for sturgeon along the North Coast of California, including the Klamath River. These regulations do not apply to the tribal gill net fishery (USFWS 1995).

Habitat Protection

Green sturgeon could potentially benefit from the ESA listing of other fish species that overlap their range. For example, numerous stocks of salmonids in the Pacific Northwest have recently been listed under the Act, as well as estuarine species in the Sacramento-San Joaquin Delta such as Delta smelt and the Sacramento splittail. Numerous federal, state, and local restoration initiatives have been undertaken to restore several large river systems where green sturgeon occur, mostly for the benefit of salmonid populations. Restoration actions undertaken to restore these species could have some positive benefits for green sturgeon, for example, the opening of the gates on Red Bluff Diversion Dam for most of the year to allow salmon passage has apparently allowed green sturgeon to spawn above the dam. However, since the habitat needs of green sturgeon are so poorly understood, actions undertaken for other fish species can not be counted on to restore or recover the green sturgeon.

The Cal-Fed process for the Central Valley and Sacramento-San Joaquin Delta is attempting to address the negative impacts of dams, water diversions, and habitat destruction. However, this process is far from complete, and there is no guarantee that it will result in improved river conditions for green sturgeon. Water users and power companies have vowed to sue to block implementation. Despite the existence and intentions of CALFED, water projects damaging to fish habitat are being allowed to continue in the Sacramento River system. Water exports from the Delta were the second highest amount on record

in 2000 (6.30 million acre-feet) (DWR 2001). In 2001, the U. S. Bureau of Reclamation sanctioned a plan for the East Bay Municipal Utilities District to draw as much as 133,000 acre feet of water each year from the lower Sacramento River, even during drought years.

For 92 years, a large portion of the Eel River's summertime flows have been diverted to the Russian River. Two dams owned and operated by PG&E on the Eel River currently divert almost 90% of summer flows to Sonoma County through the Russian River. A recent report by American Rivers lists the Eel River as the third most imperiled river in the country, due in part to California's critical energy situation - which may encourage further hydropower production. As part of the Federal Energy Regulatory re-licensing process for the Potter Valley Project, the Federal Energy Regulatory Commission has proposed a 15% cut in flows diverted from the Eel River. However, NMFS has recommended that more than 15 % additional water be left in the Eel River to revive coho, chinook, and steelhead runs. This re-licensing is also not finalized, is a long way from implementation, and will undoubtedly face lawsuits.

Studies are underway in the Klamath basin to determine river flows required to restore tribal fisheries and coho salmon, which is listed as a federally threatened species. However, the needs of the green sturgeon are not considered in these studies, due to the lack of scientific information on the spawning and nursery requirements of the species. The Department of the Interior released an Environmental Impact Statement ("EIS") in 2001 that recommends flow increases on Trinity River. Although the Trinity plan calls for an average annual increase of 250,000 acre-feet of water to be released for fishery restoration, it still allows over half of Trinity River flows to continue to be diverted to the Central Valley. The change in operation of the Trinity River could potentially benefit sturgeon there, but could also impact Sacramento River sturgeon because of changes in flows. This EIS is also a long way from implementation, and again, water users and power companies will sue to block implementation.

Existing regulatory mechanisms have failed to protect populations of the green sturgeon. Furthermore, appropriate protective mechanisms should be conservative in proportion to the existing uncertainties about stock structure and status of green sturgeon populations. The broad habitat needs of green sturgeon suggest that only large-scale, system-wide habitat protection and improvement programs can be expected to provide significant benefits for populations that are depleted or threatened by habitat alteration. System-wide changes in the large river systems they inhabit now pose serious risks to sturgeons - their large riverine habitats are on the verge of ceasing to function at the ecosystem level.

Except in rare cases, site specific changes can be expected to have little effect. Managers have had to rely on harvest management, as system-wide habitat protection and enhancement measures have been extremely difficult to implement because they involve complex issues of water diversion, land use, and hydro power operation. Efforts which do not address habitat degradation will fail to restore sturgeon populations to historic levels of productivity. Only a combination of alternatives integrating habitat protection and recovery with harvest restrictions will work (Beamesderfer and Farr 1997).

The USFWS has set an overall restoration criteria for green sturgeon of a minimum of 1,000 fish over 1 m in length. This criteria is flawed for several reasons. First, restoration criteria should be expressed as an annual spawner escapement objective in terms of egg potential or biomass of females. It is especially important to use eggs or females as criteria in a species where the sexes have significant differences in parameters such as growth, natural mortality, and fishing mortality. Second, annual recovery goals are needed due to high variability in year-to-year spawning success. A population of over 1000 fish of spawning size during a wet year with optimal spawning conditions could easily drop to the low hundreds in successive years. Lastly, restoration criteria should be applied to stocks, or spawning populations of green sturgeon. A minimum of over 1000 green sturgeon overall does not reflect whether the spawning population in a particular river system has dipped below the threshold of long-term viability. The loss of any of the remaining spawning populations could be catastrophic for the species.

5. Other Natural or Anthropogenic Factors

a. Entrainment

The powerful federal Central Valley Project (“CVP”) and State Water Project (“SWP”) pumping plants in the Sacramento-San Joaquin Delta have had a major and often detrimental effect on stream flow in the Delta and the San Joaquin River Basin. During periods of low water flow and high quantities of exports, the Delta pumps actually reverse the flow of the San Joaquin River, taking it back upstream. Through the Delta’s transport system, water normally traveling to the west, toward San Pablo Bay, instead moves back toward the east and south. The reverse flows disorient and delay migratory fish, often luring them to the pumps where they are entrained, increase predation at water facilities, and draw salty ocean water into the San Joaquin River and other waterways. (Reynolds et al. 1993; NMFS 1996).

Juvenile green sturgeon and an occasional adult sturgeon are entrained on an irregular basis in at both facilities. The numbers vary enormously from year to year and it is not known if the numbers represent a significant part of the population. It is likely some of the green sturgeon captured at the pumping plants and returned to the Delta survive the experience, but the actual survival rate is not known. The discovery of 5 adult and 33 juvenile green sturgeon stranded in Clifton Court Forebay in 1992 is also cause for concern because it is not known whether or not those fish were trapped there permanently (USFWS 1995).

At the Central Valley Project pumps in the south Delta, 1,374 green sturgeon were rescued and recorded in 1985, 49 in 1986, 91 in 1987, and none from 1988-1990. Variable numbers of green sturgeon have been captured almost yearly since 1968 at the State Water Project pumps. The total number caught during the period 1968-1980 was 11,500 fish. Of these, 7,311 were recovered in 1974, 2,285 in 1975, 767 in 1978, and 0-243 in each of the remaining years. The annual numbers caught from 1981-1990 were: 412, 523, 1, 91, 3, 0, 37, 50, 0, and 123. (Moyle et al. 1992). More recent salvage data for green sturgeon at the state and federal pumps in the Delta could not be obtained.

Yolk-sac larvae coming down the Sacramento River from March to June are particularly susceptible to water diversions. Yolk-sac larvae have negligible swimming capabilities and would be unable to escape entrainment. (Skinner 1972).

b. Toxic Substances

The effects of toxic substances from heavy metals to pesticides on green sturgeon are unknown. However, for fish that spawn and rear in the Sacramento River and Delta, high exposure levels are possible, due to pervasive pesticide use in the Central Valley for agriculture. The long-lived adults may accumulate contaminants through the food chain, which could interfere with reproduction (USFWS 1995).

Sturgeon eggs and embryos are sensitive to pollutants, with some heavy metals known to be toxic at very minute concentrations (Detlaff et al. 1993). Georgi (1993) notes that the chronic effects of wild sturgeon spawning in “chemically polluted” water and rearing on contaminated sediments, in combination with bioaccumulation of contaminants in the food chain, is possibly impacting the successful reproduction and early age recruitment to the Kootenai River white sturgeon population. Partridge (1983) expressed concerns that contaminants, primarily high concentrations of zinc and copper, may inhibit survival of white sturgeon eggs and larvae. Apperson (1992) believed that “concentrations of copper found in white sturgeon oocytes present the most severe contaminant effect on reproductive success” since high copper concentrations are known to inhibit yolk uptake in larval white sturgeon. Detectable levels of aluminum, copper, lead, zinc, and strontium, along with PCBs and pesticides were found in sturgeon egg samples from the Kootenai River (Apperson 1992). Graham (1981) concluded that poor water quality, i.e. heavy metals and other contaminants, may have affected white sturgeon reproductive success and impacted the prey base in the Kootenai. (USFWS 2000a).

Bioaccumulation of polychlorinated biphenyls (PCBs) or other contaminants may reduce sturgeon survival (Emmett et al. 1991). Samples of white sturgeon gonads from the Delta in 1975 indicated concentrations of PCBs of 24 parts per million (ppm) in the eggs. PCB concentrations of 3-7 ppm in other species have been shown to increase egg and larvae mortality (Herbold and Moyle 1989). Hansen et al.

(1974) showed that a PCB concentration of 7 ppm in eggs of the sheepshead minnow, *Cyprinodon variegatus*, caused mortality in the fry, and Hogan and Brauhn (1975) found that 60-70% of rainbow trout fry were deformed 30 days after hatching due to PCB levels of 2.7 ppm in the eggs. Mortalities were also increased by PCBs in the first 30 days after hatching. PCBs gained wide use in 1930s and 1940s (Walker 1976) and are still present in the San Francisco Bay benthic food chain.

The main food item green sturgeon have been observed feeding on in Washington is the burrowing shrimp (S. Wright, pers. comm. 2001). Commercial oyster growers in Willapa Bay use a pesticide, carbaryl, to kill these shrimp, which burrow into the oyster beds, making them softer. The shrimp are mainly a problem for non-native “seed” oysters from Japan or Hood Canal. The pesticide use may directly impact green sturgeon and/or their primary summer food supply. There have been some massive Dungeness crab kills observed in Willapa Bay due to carbaryl use (S. Wright, pers. comm. 2001).

In recent years, a major item in the white sturgeon diet has been the “overbite clam” (*Potamocorbula amurensis*), which became extraordinarily abundant in Suisun Bay following its invasion in the 1980s. White sturgeon that feed on *P. amurensis* have elevated levels of selenium, which has the potential to interfere with reproduction function (P. Moyle, 2001).

III. CONCLUSION

Although complete historic data is lacking, it is clear that green sturgeon have experienced a severe recent decline in overall abundance. Of serious concern is that more former spawning populations have been extirpated in the past century (from the San Joaquin, Eel, and South Fork Trinity Rivers, probably the Umpqua River, and possibly the Fraser River as well) than currently remain in existence (in the Sacramento and Klamath/Trinity Rivers, and possibly the Rogue River). We know less about green sturgeon than any other North American sturgeon, and all sturgeon species other than the white sturgeon are considered to be threatened in one way or another. The remaining spawning populations of green sturgeon are small enough that a collapse could occur under certain conditions, yet hardly be noticed because of limited sampling.

Only two or three spawning runs of the species are known to remain, two of them quite small. Currently, probably 80-90% of all green sturgeon spawn in the Klamath River basin, representing a major reduction in their available spawning habitat. If these populations were salmonids, it is likely that the Klamath basin and Sacramento basin populations would be classified as separate Evolutionarily Significant Units, although unfortunately genetic studies to determine green sturgeon stocks are lacking. The three known or suspected spawning rivers all have flows regulated by water projects, yet there is little understanding of what green sturgeon require as far as water flows are concerned.

The biggest fisheries for green sturgeon, in Coastal Washington and the Columbia River, occur in an area with no known spawning or fish production. The largest breeding population of green sturgeon, in the Klamath basin, is subject to a growing tribal fishery which is having a likely significant impact. Green sturgeon in general are subject to sport and by-catch fisheries taking at least 4,200 fish per year at present time, and perhaps as many as 11,000 fish per year (Moyle et al. 1994; King 2001). While harvest levels are apparently less than they were 10-15 years ago, fisheries managers have no evidence that the current rate is sustainable. Regulations for the sturgeon fishery are based on protection of mature breeding age white sturgeon, not green sturgeon. Although the large minimum size does offer some protection for smaller green sturgeon, the slot limit in California to protect large white sturgeon allows for harvest of the largest and most fecund female green sturgeon.

Although some stocks of white sturgeon have shown ability to recover from severe over-fishing, there are important differences between green and white sturgeon. One critical unique feature of green sturgeon is that they are truly anadromous fish. As such, they have special energy costs for processes such as migration and osmoregulation – costs that prevent energy supplies from being converted into growth and reproductive products. It is important to note that a number of green sturgeon populations have disappeared from rivers where white sturgeon have persisted. Also in contrast to white sturgeon, no green sturgeon spawning population has ever demonstrated any actual ability to recover from a markedly reduced population size. Green sturgeon may have an inherently lesser ability to provide surplus production for harvest (a very common difference between fish species, and even stocks within a species). The difference in ability to persist also suggests that green sturgeon may have certain unique compensatory mortality factors that take an increasing percentage of progressively smaller populations. An ominous possibility is that when this type of population drops below a certain threshold, it is doomed to extinction.

A recent American Fisheries Society assessment (Musick et al. 2000) that there are likely only a few hundred mature females left in the few remaining breeding populations of green sturgeon should ring alarm bells for fisheries managers. It is not known whether any of these populations interbreed or whether they should be considered as separate stocks rapidly approaching the critical threshold for reproductive and genetic viability. The green sturgeon warrants immediate listing as an endangered or threatened species to protect existing populations and their remaining spawning habitat.

IV. CRITICAL HABITAT

Petitioners request the designation of critical habitat for the green sturgeon concurrent with its listing. The green sturgeon already has vanished from many areas in its historic range. Critical habitat should encompass all known and potential spawning rivers and major feeding areas for the species.

V. SIGNATURE PAGE

Submitted this 6th day of June 2001

Cynthia Elkins
Environmental Protection Information Center
P.O. Box 397
Garberville, CA 95542
(707) 923-2931

Jeff Miller
Center for Biological Diversity
P.O. Box 40090
Berkeley, CA 94704-4090
(510) 841-0812

Jonathan Kaplan
WaterKeepers Northern California
Presidio Building 1004
San Francisco, CA 94129
(415) 561.2299 ext. 14

APPENDIX 1

**California and Coastal Oregon
Green Sturgeon Sport Catch¹**

Year	SF Bay/ Sac. River ²	Klamath River	Oregon Coastal ³	Total
1985	few	few	-	
1986	few	few	153	153+
1987	few	few	170	170+
1988	few	few	258	258+
1989	few	few	202	202+
1980s avg.	few	few	191	196+
1990	est. 53-78	few	157	210+
1991	est. 53-78	few	366	419+
1992	est. 53-78	closed	197	250+
1993	est. 53-78	closed	293	346+
1994	est. 53-78	closed	160	213+
1995	est. 53-78	closed	78	131+
1996	est. 53-78	closed	210	263+
1997	est. 53-78	closed	158	211+
1998	est. 53-78	closed	103	156+
1999	est. 53-78	closed	no data	53+
1990s avg.	est. 53-78		191	244+

¹ Data provided by Steve King, OR Dept of Fish and Wildlife; Dave Kohlhorst, CA Dept of Fish and Game, Sacramento CA.

² The CA Dept of Fish and Game does not keep data on green sturgeon sport catch in the SF Bay/Sacramento River basin. 1990-1999 estimates based on green sturgeon population estimates provided by Dave Kohlhorst, CDFG, and assuming a green sturgeon catch rate similar to catch rates for white sturgeon during the early 1990s (8-11.5%).

³ Does not include lower Columbia River sport catch.

Klamath River Green Sturgeon Catch¹

Year	Yurok ²	Hoopa ³	Karuk ⁴	Poaching ⁵	Total
1980	700+	-	unknown	400+	1100+
1981	880+	-	unknown	70+	950+
1982	397+	-	unknown	50+	447+
1983	406+	-	unknown	unknown	406+
1984	394+	-	unknown	unknown	394+
1985	351+	10	unknown	unknown	361+
1986	421+	30	unknown	unknown	451+
1987	171+	20	unknown	unknown	191+
1988	212+	20	unknown	unknown	232+
1989	268+	30	unknown	unknown	298+
1980s avg.	420+	22	unknown	unknown	483+
1990	242+	20	unknown	unknown	262+
1991	312+	13	unknown	unknown	325+
1992	212+	3	unknown	unknown	215+
1993	417+	10	unknown	unknown	427+
1994	293+	14	unknown	unknown	307+
1995	131+	2	unknown	unknown	133+
1996	119+	17	unknown	unknown	136+
1997	306+	7	unknown	unknown	313+
1998	335+	10	unknown	unknown	345+
1999	184+	27	unknown	unknown	211+
1990s avg.	255+	12	unknown	unknown	267+

¹ Data provided by John DeVore, Washington Dept. of Fish and Wildlife, Vancouver WA; Steve King, Oregon Dept. of Fish and Wildlife.

² Available harvest estimates are biased low by variable and inconsistent sampling effort based on volunteered data. Some Yurok harvest occurs prior to the annual monitoring activities of the US Fish and Wildlife Service.

³ US Fish and Wildlife Service data only available from 1985. Available harvest estimates are biased low by variable and inconsistent sampling effort based on volunteered data.

⁴ Karuk harvest is not monitored by the US Fish and Wildlife Service.

⁵ Illegal snag harvest occurred at Coon Creek Falls after 1977, where a debris slide created a migration obstacle.

APPENDIX 2

APPENDIX 3

Lower Columbia River Green Sturgeon Catch¹

Year	Commercial Poundage	Commercial	Sport	Total
1938	10800	-		
1939	16100	-		
1940	15300	-		
1941	10100	-		
1942	5500	-		
1943	6100	-		
1944	11100	-		
1945	19000	-		
1946	16900	-		
1947	11800	-		
1948	11300	-		
1949	18900	-		
1950	33000	-		
1951	22300	-		
1952	35100	-		
1953	34700	-		
1954	30100	-		
1955	70800	-		
1956	50700	-		
1957	112800	-		
1958	76600	-		
1959	192200	-		
1960	71300	1800		1800
1961	119200	3000		3000
1962	65300	1600		1600
1963	50300	1200		1200
1964	30000	800		800
1965	32400	800		800
1966	70900	1800		1800
1967	46100	1100		1100
1968	24700	600		600
1969	68400	1700		1700
Average				1440
1970	51100	1300		1300
1971	52400	1300		1300
1972	46200	1100		1100
1973	34500	1300		1300
1974	121800	3100		3100
1975	42900	1300		1300
1976	89500	3000		3000
1977	23500	800	0	800
1978	48700	1700	0	1700
1979	36800	1200	0	1200
Average				1610

Year	Commercial Poundage ²	Commercial ¹	Sport ³	Total
1980	44600	1700	0	1700
1981	5100	200	0	200
1982	24400	800	0	800
1983	18600	700	100	800
1984	84500	2700	100	2800
1985	41000	1600	533	2133
1986	180600	6000	407	6407
1987	145700	4900	228	5128
1988	114100	3300	141	3441
1989	47800	1700	84	1784
Average				2519
1990	64900	2200	86	2286
1991	89000	3190	22	3212
1992	62300	2160	73	2233
1993	66400	2220	15	2235
1994	6400	240	132	372
1995	11300	390	21	411
1996	19600	610	63	673
1997	59400	1614	41	1655
1998	31200	894	73	967
1999	32900	1362	93	1455
Average				1550

¹ Data provided by John DeVore, Washington Dept. of Fish and Wildlife, Vancouver WA; Steve King, Oregon Dept. of Fish and Wildlife.

² Target sturgeon gillnet seasons eliminated 1989-1996.

³ Sport catch estimates only available in WA since 1988; in OR since 1986.

Catch estimates depend upon voluntary return of catch cards and are likely underestimates.

APPENDIX 4

Grays Harbor & Willapa Bay Green Sturgeon Catch

Grays Harbor					Willapa Bay				
Year	Commercial Pounds	Commercial Catch/2	Tribal	Sport	Grays Harbor Total	Commercial Pounds	Commercial Catch/2	Sport	Willapa Bay Total
1953	14,161	430			430	29,609	900		900
1954	14,727	448			448	13,064	397		397
1955	14,208	432			432	20,712	630		630
1956	26,503	806			806	65,428	199		199
1957	32,535	989			989	9,016	274		274
1958	31,513	958			958	10,157	309		309
1959	74,289	2,258			2,258	19,347	588		588
Average		903			903		471		471
1960	65,727	1,998			1,998	32,251	980		980
1961	84,474	2,568			2,568	41,080	1,249		1,249
1962	74,625	2,268			2,268	19,422	590		590
1963	47,123	1,432			1,432	28,436	864		864
1964	44,654	1,357			1,357	36,265	1,102		1,102
1965	23,590	717			717	29,275	890		890
1966	40,322	1,226			1,226	73,936	2,247		2,247
1967	34,490	1,048			1,048	83,426	2,536		2,536
1968	31,222	949			949	70,685	2,148		2,148
1969	39,329	1,195			1,195	99,000	3,009		3,009
Average		1,476			1,476		1,562		1,562
1970	-	1,168			1,168	-	3,924		3,924
1971	-	886			886	-	4,112		4,112
1972	-	581			581	-	2,482		2,482
1973	-	475			475	-	1,886		1,886
1974	-	600			600	-	1,359		1,359
1975	-	272			272	-	1,464		1,464
1976	-	278			278	-	2,137		2,137
1977	-	509			509	-	1,052		1,052
1978	-	212			212	-	737		737
1979	-	230			230	-	1,291		1,291
Average		521			521		2,044		2,044
1980	-	750			750	-	1,207		1,207
1981	-	512			512	-	1,298		1,298
1982	-	1,216			1,216	-	817		817
1983	-	504			504	-	769		769
1984	-	353			353	-	1,184		1,184
1985	-	231	5		236	40,997	1,289		1,289
1986	-	632	3		635	30,024	925		925
1987	-	776	5		781	27,716	877		877
1988	18,101	609	1	4	614	51,519	1,598	1	1,599
1989	24,332	870	2	12	884	14,897	461	4	465
Average		645	5	8	649		1,043	3	1,043

Grays HarborWillapa Bay

Year	Commercial Poundage	Commercial Catch/2	Tribal ³	Sport ⁴	Grays Harbor Total	Commercial Poundage	Commercial Catch/2	Sport ⁴	Willapa Bay Total
1990	21,544	734	9	4	747	30,572	953	2	955
1991	43,596	1,527	3	0	1,530	30,089	957	0	957
1992	-	737	3	0	740	32,984	1,002	0	1,002
1993	-	542	3	112	657	9,183	290	32	322
1994	-	17	22	25	64	9,093	268	13	281
1995	-	374	185	92	651	2,524	78	12	90
1996	5,349	137	153	71	361	4,555	129	24	153
1997	6,790	201	197	117	515	178	16	4	20
1998	-	25	53	29	107	-	65	12	77
1999	-	14	56	no data	70	-	9	no data	9
Average		431	68	50	544		377	11	387

¹ Data provided by John DeVore, WA Dept. of Fish and Wildlife, Vancouver WA; Steve King, OR Dept. of Fish and Wildlife.

² 1953-1969 and 1974-1984 landings based on total poundage divided by the 1985 -1991 average Lower Columbia River white sturgeon sampled weight (32.9 lbs./fish). Includes setline landings (< 25/year) which were prohibited as of 1990. There has been no early gillnet season (July to mid-August) from 1994 to present, potentially reducing catches somewhat, primarily in Willapa Bay.

³ Catch estimates available only since 1985.

⁴ Catch estimates available only since 1988. Estimates depend upon voluntary return of catch cards and are likely underestimated.

APPENDIX 5

Washington and Oregon Trawl Catch of Green Sturgeon¹

Year	<u>Washington</u>		<u>Oregon</u>		<u>Combined</u>		Estimated Number of Fish ²
	Deliveries	Pounds	Deliveries	Pounds	Deliveries	Pounds	
1981	60	4064	104	8591	164	12655	388
1982	73	11153	164	13752	237	24905	764
1983	41	2323	156	12074	197	14397	442
1984	22	1427	169	23264	191	24691	757
1985	95	11699	171	23671	266	35370	1085
1986	41	4005	100	6203	141	10208	313
1987	35	2117	64	4055	99	6172	189
1988	30	1206	48	3899	78	5105	157
1989	63	4172	100	6833	163	11005	338
Average							443
1990	37	2259	73	4668	110	6927	212
1991	69	3268	100	7875	169	11143	342
1992	35	1935	53	3062	88	4997	153
1993	20	1128	88	8139	108	9267	284
1994	5	174	52	5021	57	5195	159
1995	5	181	17	948	22	1129	35
1996	1	17	31	5946	32	5963	183
1997 ³	5	146	50	14535	55	14681	404
1998 ⁴	0	0	33	2214	33	2214	62
1999 ⁵	3	112	13	817	16	929	24
							186

¹ Data provided by John DeVore, Washington Dept. of Fish and Wildlife, Vancouver WA; Richard Brix, Washington Dept. of Fish and Wildlife, Montesano, WA.

² Estimate made from average weight of green sturgeon from 1991 lower Columbia River gillnet fishery; 32.6 pounds

³ 1997 average weight for green sturgeon landed in Oregon was 36.3 pounds.

⁴ The maximize size limit for green sturgeon landed in ocean trawl fisheries decreased from 72" to 66 ".

1998 Columbia River gillnet average weight for the same size fish was 35.5 pounds for green sturgeon.

⁵ 1999 Columbia River gillnet average weight for the same size fish was 39.5 pounds for green sturgeon.

APPENDIX 6

Overall Green Sturgeon Catches 1960-1999

Year	CA & OR Sport Catch	Klamath River	Lower Columbia River	Grays Harbor	Willapa Bay	WA & OR Trawl	Total
1999	53	211	1,455	70	9	24	1,822
1998	156	345	967	107	77	62	1,714
1997	211	313	1,655	515	20	404	3,118
1996	263	136	673	361	153	183	1,769
1995	131	133	411	651	90	35	1,451
Average	163	228	1,032	341	70	142	1,975
1994	213	307	372	64	281	159	1,396
1993	346	427	2,235	657	322	284	4,271
1992	250	215	2,233	740	1,002	153	4,593
1991	419	325	3,212	1,530	957	342	6,785
1990	210	262	2,286	747	955	212	4,672
Average	288	307	2,068	748	703	230	4,343
1989	202	298	1,784	884	465	338	3,971
1988	258	232	3,441	614	1,599	157	6,301
1987	170	191	5,128	781	877	189	7,336
1986	153	451	6,407	635	925	313	8,884
1985	-	361	2,133	236	1,289	1,085	5,104
Average	157	307	3,779	630	1,031	416	6,319
1984	-	394	2,800	353	1,184	757	5,488
1983	-	406	800	504	769	442	2,921
1982	-	447	800	1,216	817	764	4,044
1981	-	950	200	512	1,298	388	3,348
1980	-	1,100	1,700	750	1,207	-	4,757
Average	-	659	1,260	667	1,055	470	4,112
1979	-	-	1,200	230	1,291	-	2,721
1978	-	-	1,700	212	737	-	2,649
1977	-	-	800	509	1,052	-	2,361
1976	-	-	3,000	278	2,137	-	5,415
1975	-	-	1,300	272	1,464	-	3,036
Average	-	-	1,600	300	1,336	-	3,236
1974	-	-	3,100	600	1,359	-	5,059
1973	-	-	1,300	475	1,886	-	3,661
1972	-	-	1,100	581	2,482	-	4,163
1971	-	-	1,300	886	4,112	-	6,298
1970	-	-	1,300	1,168	3,924	-	6,392
Average	-	-	1,620	742	2,753	-	5,115

Year	CA & OR Sport Catch	Klamath River	Lower Columbia River	Grays Harbor	Willapa Bay	WA & OR Trawl	Total
1969	-	-	1,700	1,195	3,009	-	5,904
1968	-	-	600	949	2,148	-	3,697
1967	-	-	1,100	1,048	2,536	-	4,684
1966	-	-	1,800	1,226	2,247	-	5,273
1965	-	-	800	717	890	-	2,407
Average	-	-	1,200	1,027	2,166	-	4,393
1964	-	-	800	1,357	1,102	-	3,259
1963	-	-	1,200	1,432	864	-	3,496
1962	-	-	1,600	2,268	590	-	4,458
1961	-	-	3,000	2,568	1,249	-	6,817
1960	-	-	1,800	1,998	980	-	4,778
Average	-	-	1,680	1,925	957	-	4,562

VII. BIBLIOGRAPHY

- Andriyashev, A. P., and K. I. Panin. 1953. Discovery of a Pacific sturgeon (*Acipenser medirostris* Ayres) in the Bering Sea. *Zool. Zhurnal* 32(5), 932-936.
- Aplin, J. A. 1967. Biological survey of San Francisco Bay 1963-1966. California Department of Fish and Game, Marine Resources Operations Laboratory. Marine Resources Operations Reference # 67-4, 131 pp.
- Artyukhin, E. N, A. D. Sukhoparova, and L. G. Fimukhina. 1979. The gonads of the sturgeon, *Acipenser guldenstadti*, in the zone below the dam of the Volgograd water engineering system. *Journal of Ichthyology* 18:912-923.
- Artyukhin, E. N. and A. E. Andronov. 1991. A morphobiological study of the green sturgeon, *Acipenser medirostris* (Chondrostei, Acipenseridae) from the Tummin (Datta) River and some aspects of the ecology and zoogeography of Acipenseridae. *Zoologicheskiy zhurnal* 69(12): 81-91 (1990).
- Ayres, W. O. 1854. Descriptions of three new species of sturgeon from San Francisco. *Proceedings of the California Academy of Natural Sciences* 1: 14-15 (1854-1857).
- Bajkov, A. D. 1949. A preliminary report on the Columbia River sturgeon. In *Fish Commission Research Briefs* 2(2) (1949). Fish Commission of Oregon.
- Bane, G. W. and A. W. Bane. 1971. Bay fishes of northern California. Mariscos Publications, Hampton Bays, NY, 143 pp.
- Beamesderfer, R. C. and R. A. Farr. 1997. Alternatives for the protection and restoration of sturgeons and their habitat. *Environmental Biology of Fishes* 48: 407-417 (1997).
- Beamesderfer, R. C. 1997. Management and trade of Pacific sturgeon. Oregon Department of Fish and Wildlife. Clackamas, Oregon.
- Bearss, E.C. 1981. Historical resource study - Hoopa-Yurok fisheries suit, Hoopa Valley Indian Reservation - Del Norte and Humboldt Counties, California. Denver Service Center. Denver, Colorado. 443 pp.
- Berg, L. S. 1948. Freshwater fishes of the U.S.S.R. and the adjacent countries. Vol. I, fourth edition. Academy of Sciences of the U.S.S.R. Zoological Institute. Published for the National Science Foundation, Washington, D. C. by the Israel Program for Scientific Translations, Jerusalem 1962.
- Birstein, V. J. 1993. Is *Acipenser medirostris* one or two species? *The Sturgeon Quarterly* 1(2): 8 (1993).
- Birstein, V. J. 1993a. Sturgeons and paddlefishes: threatened fishes in need of conservation. *Conservation Biology* 7(4): 773-787 (1993).
- Birstein, V. J., A. I. Poletaev, and B. F. Goncharov. 1993. DNA content in Eurasian sturgeon species determined by flow cytometry. *Cytometry* 14(4): 377-383 (1993).
- Birstein, V. J. and W. E. Bemis. 1997. How many species are there within the genus *Acipenser*? *Environmental Biology of Fishes* 48: 157-163 (1997).
- Birstein, V. J., R. Hanner, and R. DeSalle. 1997. Phylogeny of the Acipenseriformes: cytogenic and molecular approaches. *Environmental Biology of Fishes* 48: 127-155.
- Birstein, V. J. and R. DeSalle. 1998. Molecular phylogeny of Acipenserinae. *Molecular Phylogenetics and Evolution* 9: 141-155.

- Blacklidge, K. H. and C. A. Bidwell. 1993. Three ploidy levels indicated by genome quantification in *Acipenseriformes* of North America. *Journal of Heredity* 84(6): 427-430 (1993).
- Blunt, C. E. 1980. Atlas of California coastal marine resources. California Department of Fish and Game, Sacramento, CA, 134 pp.
- BPA (Bonneville Power Administration). 2000. Columbia River sturgeon. World Wide Web electronic publication. www.efw.bpa.gov/.
- Boreman, J. 1997. Sensitivity of North American sturgeons and paddlefish to fishing mortality. *Environmental Biology of Fishes* 48: 399-405 (1997).
- Borodin, A. L. 1984. The red book of USSR: Species of animals and plants in danger of extinction. Vol. 1. Moscow Forest Industry - 2nd edition.
- Bottom, D. L. and B. Forsberg. 1978. The fishes of Tillamook Bay. Final Report, Fish Research Project. Oregon Department of Fish and Wildlife, 55 pp.
- Bottom, D. L., K. K. Jones, and M. J. Herring. 1984. Fishes of the Columbia River Estuary. Oregon Department of Fish and Wildlife, Columbia River Estuary Data Development Program, Corvallis, Oregon.
- Bottom, D. L., P. J. Howell, and J. D. Rogers. 1985. The effects of stream alterations on salmon and trout habitat in Oregon. Oregon Department of Fish and Wildlife. 70 p.
- Brennan, J. S. and G. M. Cailliet. 1991. Age determination and validation studies of white sturgeon, *Acipenser transmontanus*, in California. *In*: P. Williot, ed., *Acipenser*. Bordeaux: CEMAGREF.
- Brix, R. 2000. Fisheries data from Richard Brix, WDFW, supplied by Sam Wright.
- Brown, J. R., K. Beckenbach, A. T. Beckenbach, and M. J. Smith. 1996. Length variation, heteroplasmy and sequence divergence in the mitochondrial DNA of four species of sturgeon (*Acipenser*). *Genetics* 142: 525-535.
- CAS (California Academy of Sciences). 1993. California Academy of Sciences computerized catalog of the fish collection. California Academy of Sciences, San Francisco, California.
- CDFG (California Department of Fish and Game). 1992. Sturgeon in relation to water development in the Sacramento-San Joaquin estuary. Entered by the California Department of Fish and Game for the State Water Resources Control Board 1992 Water Rights Phase of the Bay-Delta Estuary Proceedings.
- CDFG (California Department of Fish and Game). 1994. Central Valley anadromous fish annual run-size, harvest, and population estimates, 1967 through 1991. August 1994 revision.
- CDFG and GCID (California Department of Fish and Game and Glenn-Colusa Irrigation District). 1994. 1986-1994 sturgeon capture data. From Sacramento CDFG files.
- CDFG. 2000. California Department of Fish and Game green sturgeon files. Produced by Dave Kohlhorst in response to a California Public Records Act request. Available from the California Department of Fish and Game, Sacramento, California.
- Carl, G. C. and W. A. Clemens. 1948. The fresh-water fishes of British Columbia. British Columbia Provincial Museum Department of Education, Handbook No. 5, Victoria, B.C.
- Chadwick, H. K. 1959. California sturgeon tagging studies. *California Fish and Game* 45(4): 297-301

(1959).

Chapman, F. A. 1989. Sexual maturation and reproductive parameters of wild and domestic stocks of white sturgeon, *Acipenser transmontanus*. Ph.D. Dissertation, University of Idaho, Moscow. 52 pp.

Choudhury, A. and T. A. Dick. 1998. The historical biogeography of sturgeons (Osteichthyes: Acipenseridae): a synthesis of phylogenetics, paleontology and palaeogeography. *Journal of Biogeography* 25(4): 623-640 (1998).

CH2M Hill. 1985. Klamath River Basin Fisheries Resource Plan. Report to U.S. Department of the Interior, CH2M Hill, Bellevue, WA.

Chui, G. 1999. Jammin' for the salmon. Article in the January 26, 1999 edition of the San Jose Mercury News.

Cleaver, F.C. 1951. Fisheries statistics of Oregon. Oregon Fish Commission, Portland Oregon, Contribution No. 16.

Clemens, W. A. and G. V. Wilby. 1961. Fishes of the Pacific coast of Canada. Fisheries Research Board of Canada, Bulletin No. 68.

Collins, J. W. 1892. Report on the fisheries of the Pacific coast of the United States. Appendix II, Rept. U. S. Comm. Fish., 1888 (1892), p. 3-260. Washington.

Conte, F. S., S. I. Doroshov, P. B. Lutes, and E. M. Strange. 1998. Hatchery manual for the white sturgeon *Acipenser transmontanus* with applications to other North American Acipenseridae. Publication 3322, University of California Cooperative Extension, Division of Agriculture and Natural Resources, Davis, California.

Craig, J. A. and R. L. Hacker. 1940. The history and development of the fisheries of the Columbia River. Bulletin of the Bureau of Fisheries, Vol. XLIX: 133-216.

Craig, J. L. and T. S. Fletcher. 1994. Annual report, Klamath River fisheries assessment program 1992. U. S. Fish and Wildlife Service Coastal California Fisheries Assistance Office, Arcata, California, Report No. AFF1-FRO-94-03.

Cummings, E. and E. Schwartz. 1971. Fish in Coos Bay, Oregon, with comments on distribution, temperature, and salinity of the estuary. Oregon Fish Commission Research Division. Coastal Rivers Investigations Information Report 70-11.

Dadswell, M. J.. 1979. Biology and population characteristics of the shortnose sturgeon, *Acipenser brevirostrum* LeSueur 1818 (Osteichthyes: Acipenseridae), in the Saint John River estuary, New Brunswick, Canada. *Canadian Journal of Zoology* 57.

DeLacy, A.C., B. S. Miller, and S. F. Borton. 1972. Checklist of Puget Sound Fishes. Wash. Sea Grant, Div. Mar. Res., Univ. Wash., Seattle, 43 p.

Dees, L. T. 1961. Sturgeons. Bur. Comm. Fish., Fish Leaflet #526, 8 pp.

DWR (Department of Water Resources). 2001. Data provided by Warren Dibben, DWR, Department of Records and Reports, Sacramento, CA.

Deschamps, G., S. G. Wright, and R. E. Watson. 1971. Fish migration and distribution in the lower Chehalis River and upper Grays Harbor. In Grays Harbor cooperative water quality study 1964-1966, p. 1-55. Tech. Rept. No. 7, Washington Department of Fisheries. 1971.

Detlaff, T. A., A. S. Ginsburg, and O. I. Schmalhausen. 1993. Sturgeon fishes: developmental biology and aquaculture. Springer-Verlag, New York.

De Vore, J. and B. James. 1999. Columbia River white sturgeon current stock status and management implications. Washington Department of Fish and Wildlife, Report No. SS 99-08.

Emmett, R. L., S. A. Hinton, S. L. Stone, and M. E. Monaco. 1991. Distribution and abundance of fishes and invertebrates in west coast estuaries, Volume II: Species life histories summaries. ELMR Report No. 8., NOS/NOAA Strategic Environmental Assessment Division, Rockville, MD, 329 pp.

Evermann, B. W. and Goldsborough, E. L. 1907. The fishes of Alaska. Bulletin of the Bureau of Fisheries, vol. 26.

FCO and OSGC (Fish Commission of Oregon and the Oregon State Game Commission). 1946. The Umpqua River study. The Fish Commission of Oregon and the Oregon State Game Commission.

FCO and WDF (Fish Commission of Oregon and Washington Department of Fisheries). 1972. Status report, Columbia River fish runs 1938-1970, 1971 addendum. Joint Investigational Report 1(2).

Fitch, J. E. and R. J. Lavenberg. 1971. Marine food and game fishes of California. University of California Press, Berkeley, CA, 179 pp.

Fitch, J. E. and S. A. Schultz. 1978. Some rare and unusual occurrences of fishes off California and Baja California. California Fish and Game 64(2): 74-92 (1978).

Foley, P. 1994. Patrick Foley, U. C. Davis, October 1, 1994 letter to CDFG, Rancho Cordova, CA.

Forsberg, B. O., J. A. Johnson, and S. M. Klug. 1977. Identification, distribution, and notes on food habits of fish and shellfish in Tillamook Bay, Oregon. Federal Aid Progress Reports - Fisheries. Oregon Department of Fish and Wildlife.

Fry, D. H., Jr. 1979. Anadromous fishes of California, revised edition. California Department of Fish and Game, Sacramento, California, 112 pp.

Galbreath, J. L. 1979. Columbia River colossus, the white sturgeon. Oregon Wildlife. March 1979.

Galbreath, J. L. 1985. Status, life history, and management of Columbia River white sturgeon, *Acipenser transmontanus*. Environmental Biology of Fishes 14(1).

Ganssle, D. 1966. Fishes and decapods of San Pablo and Suisun Bays. In Ecological Studies of the Sacramento-San Joaquin Estuary, Part I (compiled by D. W. Kelley), pp 64-94. California Department of Fish and Game Fish Bulletin 133.

Gaumer, T., D. Demory, and L. Osis. 1973a. 1971 Coos Bay resource use study. Fish Commission of Oregon, Division of Management and Research.

Gaumer, T., D. Demory, and L. Osis. 1973b. 1971 Umpqua River Estuary resource use study. Fish Commission of Oregon, Division of Management and Research.

Gaumer, T., D. Demory, and L. Osis. 1973c. 1971 Siletz River Estuary resource use study. Fish Commission of Oregon, Division of Management and Research.

Gaumer, T., D. Demory, and L. Osis. 1973. 1971 Columbia River Estuary resource use study. Fish Commission of Oregon, Division of Management and Research.

Gaumer, T., D. Demory, L. Osis, and C. Waters. 1974. 1970-71 Yaquina Bay resource use study. Fish Commission of Oregon, Division of Management and Research.

Giguere, Paul E. 1970. The natural resources of Bolinas Lagoon, their status and future.

Gilbert, C. H. 1897. The fishes of the Klamath Basin. Bulletin of the United States Fish Commission 17: 1-13.

Gilbert, C. H. 1904. Notes on fishes from the Pacific Coast of North America. Proceedings of the California Academy of Sciences, 3rd Series Zoology, Vol. III, No. 9.

Glavin, T. 1996. Dead reckoning: confronting the crisis in Pacific fisheries. Greystone Books, Vancouver, British Columbia. 181 pp.

Gotshall, D. W., G. H. Allen, and R. A. Barnhart. 1980. An annotated checklist of fishes from Humboldt Bay, California. California Fish and Game 66(4): 220-232 (1980).

Graham, P. 1981. Status of white sturgeon in the Kootenai River. Montana Dept. of Fish, Wildlife, and Parks. Kalispell, Montana. Jan. 1981. Mimeo, 26p.

Green, R. E. 1975. A preliminary list of fishes collected from Richardson Bay, California 1972-1973. California Fish and Game 61(2): 104-106 (1975).

Hallock, R. J. 1968. Efficiency tests of the primary louver system, Tracy fish screen. California Department of Fish and Game, Sacramento, CA.

Halkett, A. 1913. Check list of the fishes of the dominion of Canada and Newfoundland.

Hansen, D. J., S. C. Schimmel, and J. Forester. 1974. Aroclor 1254 in eggs of sheepshead minnows: effects on fertilization success and survival of embryos and fry. Southeastern Assoc. Game Fish Comm., Proceedings of the 27th Annual Conference, p. 420-426.

Harkness, W. J. 1923. The rate of growth and the food of the lake sturgeon (*Acipenser rubicundus* Le Sueur). University of Toronto Studies. Publication of the Ontario Fisheries Research Laboratory, No. 18, Toronto.

Hart, J. L. 1973. Pacific fishes of Canada. Fisheries Research Board of Canada, Bulletin 180: 82.

Healy, T. P., Jr. 1970. Studies of steelhead and salmon emigration in the Trinity River. California Department of Fish Game, Anadromous Fisheries Branch Administrative Report No. 73-1, 37 pp.

Herbold, B. and P. B. Moyle. 1989. The Ecology of the Sacramento-San Joaquin Delta: A Community Profile. U. S. Fish and Wildlife Service, National Wetlands Research Center, Biological Report 85(7.22).

Hilgendorf, F. 1892. Über eine neue Stor-Art aus Nord-Japan (*Acipenser mikadoi*). Sitzungsber. Ges. Naturf. Freunde. Berlin, 142-144.

Hogan, J. W. and J. L. Brauhn. 1975. Abnormal rainbow trout fry from eggs containing high residues of PCB (Aroclor 1242). Prog. Fish. Cult. 37(4): 229-230.

Hoopa Valley Tribal Council - Fisheries Department (HVTC-FD). 1997. Tagging of green sturgeon for estimation of population size and range of migrants.

Houston, J. J. 1987. Status Report on the Green Sturgeon, *Acipenser medirostris*; Committee on the Status of Endangered Wildlife in Canada. Ottawa, Ontario, 10pp.

- Houston, J. J. 1988. Status of the green sturgeon, *Acipenser medirostris*, in Canada. Canadian Field-Naturalist 102(2): 286-290 (1998).
- Johnson, J. A., D. P. Liscia, and D. M. Anderson. 1986. The seasonal occurrence and distribution of fish in the Umpqua Estuary, April 1977 through January 1986. Oregon Department of Fish and Wildlife Information Report Number 86-6.
- Jordan, D. S. and C. H. Gilbert. 1882. Synopsis of the fishes of North America. Bulletin of the United States National Museum, No. 16: 1-1018.
- Jordan, D. S. and E. C. Starks. 1895. The fishes of Puget Sound. Proc. Cal. Acad. Sci. 5: 785-855.
- Jordan, D. S. and B. W. Evermann. 1923. American food and game fishes. Doubleday, Page & Company, Garden City, N. Y.
- Jordan, D. S. 1925. Fishes. D. Appleton and Company, New York, N. Y.
- Jung, W. 1985. North American Sturgeons; Developments in the Environmental Biology of Fishes 6
- Khoroshko, P. N. 1972. The amount of water in the Volga Basin and its effect on the reproduction of sturgeon (Acipenseridae) under conditions of normal and regulated discharge. Journal of Ichthyology 12: 608-615.
- Kim, I. 1997. Illustrated encyclopedia of fauna and flora of Korea. Vol. 37. Freshwater fishes. Ministry of Education. 1-629, 49 col. pls. (In Korean, English summ.)
- King, S. D. and G. Norman 1991. Status report: Columbia River fish runs and fisheries 1960-1990. Oregon Department of Fish and Wildlife and Washington Department of Fisheries.
- King, S. 1998. Green sturgeon - an overview of status, fisheries, and management. ODFW Intradepartment Memorandum. February 3, 1998. From ODFW files.
- King, S. D. 2000. Personal communication with Steve King, ODFW, 2000.
- King, S. D. 2001. ODFW catch data supplied by Steve King, ODFW, 2001.
- Kohlhorst, D. W. 1976. Sturgeon spawning in the Sacramento River in 1973, as determined by distribution of larvae. California Fish and Game 62(1): 32-40 (1976).
- Kohlhorst, D. W. 1980. Recent trends in the white sturgeon population in California's Sacramento-San Joaquin Estuary. California Fish and Game 66(4): 210-219 (1980).
- Kohlhorst, D. W., L. W. Botsford, J. S. Brennan, and G. M. Cailliet. 1991. Aspects of the structure and dynamics of an exploited central California population of white sturgeon (*Acipenser transmontanus*). In P. Williot (ed.). Acipenser. Proceedings of the First International Symposium on the Sturgeon. Bordeaux: CEMAGREF. pages 227-293.
- Lane, E. D. 1991. Status of the white sturgeon, *Acipenser transmontanus*, in Canada. Canadian Field-Naturalist 105: 161-168.
- Lauman, J. E., K. E. Thompson, and J. D. Fortune, Jr. 1972. Fish and wildlife resources of the Umpqua Basin, Oregon, and their water requirements. Oregon State Game Commission, Federal Aid to Fish Restoration Completion Report.

- Lindberg, G. U. and M. I. Legeza. 1965. Fishes of the Sea of Japan and the adjacent areas of the Sea of Okhotsk and the Yellow Sea. Keys to the Fauna of the U. S. S. R. Published by the Academy of the Sciences of the U.S.S.R.
- Magnin, E. 1959. Répartition actuelle des acipenserides. Rev. Trav. Inst. Pêches Marit. 23(3): 277-285.
- Magnin, E. 1963. Recherches sur la systematique et la biologie des Acipenserides *Acipenser sturio* L., *Acipenser oxyrhynchus* Mitchill, *Acipenser fulvescens* Raf. Theses a la faculte des sciences de l'Universite de Paris. Paris: Imprimerie National, 7-242.
- Mason, W. T., Jr. and J. P. Clugston. 1993. Foods of the Gulf sturgeon in the Suwanee River. Transactions of the American Fisheries Society 122: 378-385.
- Mathison, R. 1998. The history of Alderpoint. Eureka Printing Company Inc., Eureka, California.
- Matsubara, K. 1955. Fish morphology and hierarchy. Vols. 1-3. Ishizaki Shoten, Tokyo. 1605 p.
- McCabe, G. T., Jr. 1993. Prevalence of the parasite *Cystoopsis acipenseri* (Nematoda) in juvenile white sturgeons in the lower Columbia River. Journal of Aquatic Animal Health 5: 313-316. Get this paper!
- McCabe, G. T., Jr. and C. A. Tracy. 1993. Spawning Characteristics and early life history of white sturgeon *Acipenser transmontanus* in the lower Columbia River. In R. C. Beamesderfer and A. A. Nigro (ed.). Status and habitat requirements of the white sturgeon populations in the Columbia River downstream from McNary Dam, Volume I, p. 19-46, Bonneville Power Administration, Contract DE-AI79-86BP63584.
- McPhail, J. D. and C. C. Lindsey. 1970. Freshwater fishes of northwestern Canada and Alaska. Fisheries Research Board of Canada Bulletin 173: 60-61.
- McPhail, J. D. and R. Carveth. 1993. Field key to the freshwater fishes of British Columbia. Fish Museum, Department of Zoology, U. B. C., Canada. 239 p.
- Migdalski, E.C. 1962. Angler's guide to the fresh water sport fishes. Ronald Press, N.Y. 431 p.
- Miller, B.S. and S. F. Borton. 1980. Geographical distribution of Puget Sound fishes: maps and data source sheets. 3 Volumes. Wash. Sea Grant Prog. and Wash. State Dept. Ecol.
- Miller, B.S. 1991. Long-term trends in Puget Sound marine fishes: selected data sets. Bruce S. Miller, Lawrence L. Moulton and John H. Stadler. Seattle, WA : Fisheries Research Institute, School of Fisheries, University of Washington, [1991] 38 p.
- Miller, D. J. and R. V. Lea. 1972. Guide to the coastal marine fishes of California. California Department of Fish and Game, Fish Bulletin 157, 249 p.
- Miller, L. W. 1972. Migrations of sturgeon tagged in the Sacramento-San Joaquin Estuary. California Fish and Game 58(2): 102-106 (1972).
- Mills, T. J. and F. Fisher. 1994. Central Valley anadromous sport fish annual run size, harvest estimates and population trends, 1967 through 1991. 3rd Draft. Department of Fish and Game (Inland Fisheries Technical Report). Sacramento, California.
- Monaco, M. E., D. M. Nelson, R. L. Emmett, and S. A. Hinton. 1990. Distribution and abundance of fishes and invertebrates in west coast estuaries, Volume 1: Data Summaries. ELMR Report No. 4 Strategic Assessment Branch, NOS/NOAA. Rockville, MD, 240 p.
- Monroe, G. M. 1973. The natural resources of Humboldt Bay. California Department of Fish and Game,

Coastal Wetland Series #6.

Monroe, G. M. and F. Reynolds. 1974. Natural resources of the Eel River Delta. California Department of Fish and Game, Coastal Wetland Series #9, 108 pp.

Monroe, G. M., B. J. Mapes, and P. L. McLaughlin. 1975. Natural resources of Lake Earl and the Smith River Delta; California Department of Fish and Game, Coastal Wetland Series 10, 114 pp.

Mori, T. 1952. Check list of the fishes of Korea. Mem. Hyogo Univ. Agric., Biol. Ser. 1-228.

Morrow, J. E. 1980. The freshwater fishes of Alaska. Alaska Northwest Publishing, Anchorage, Alaska.

Moyle, P. B. 1976. Inland Fishes of California. University of California Press, Berkeley, 405 pp.

Moyle, P. B., P. J. Foley, and R. M. Yoshiyama. 1992. Status of green sturgeon, *Acipenser medirostris*, in California. Final Report submitted to National Marine Fisheries Service, Terminal Island, CA.

Moyle, P. B. 1994. The decline of anadromous fishes in California. Conservation Biology 8(3): 869-870 (1994).

Moyle, P. B. and R. M. Yoshiyama. 1994. Protection of aquatic biodiversity in California: A five-tiered Approach. Fisheries 19(2): 6-18 (1994).

Moyle, P.B., P. J. Foley, and R. M. Yoshiyama. 1994. Status and Biology of the Green Sturgeon, *Acipenser medirostris*. Sturgeon Quarterly 2.

Moyle, P. B., R. M. Yoshiyama, J. E. Williams, and E. D. Wikramanayake. 1995. Fish species of special concern in California, 2nd Edition. California Department of Fish and Game, Inland Fisheries Division, Rancho Cordova, CA.

Mullen, R.E. 1977. The occurrence and distribution of fish in the Umpqua River Estuary, June through October 1972. Oregon Department of Fish and Wildlife, Information Report Series, Fisheries Number 77-3.

Mulligan, H., T. Mulligan, and D. Hillemeier. 1996. Genetic analysis of Klamath River green sturgeon (interim report). Yurok Tribal Fisheries Program

Murphy, G. I. and J. W. DeWitt, Jr. 1951. Notes on the fishes and fishery of the lower Eel River, Humboldt County, California. California Department of Fish and Game, Administrative Report 51-9, 28 pp.

Musick, J. A. et al. 2000. Marine, estuarine, and diadromous fish stocks at risk of extinction in North America (exclusive of Pacific salmonids). Fisheries 25 (11): 10.

Nakamoto, R. J., T. T. Kisanuki, and G. H. Goldsmith. 1995. Age and growth of Klamath River green sturgeon (*Acipenser medirostris*). U. S. Fish and Wildlife Service, Project # 93-FP-13, Klamath River Fishery Resource Office, Yreka, CA.

NMFS and USFWS (National Marine Fisheries Service and U. S. Fish and Wildlife Service). 1974. Memorandum of Understanding between the U. S. Fish and Wildlife Service, United States Department of the Interior and the National Marine Fisheries Service, National Oceanic and Atmospheric Administration, United States Department of Commerce regarding jurisdictional responsibilities and listing procedures under the Endangered Species Act of 1973.

NMFS (National Marine Fisheries Service). 1996. Factors for decline. A supplement to the Notice of Determination for West Coast Steelhead Under the Endangered Species Act. NMFS Protected Species Branch, Portland, Oregon and NMFS Protected Species Management Division, Long Beach, California.

NMFS (National Marine Fisheries Service). 1997. NMFS Proposed Recovery Plan for the Sacramento River Winter-Run Chinook Salmon. Southwest Region, Long Beach, California.

Nikol'skii, G. V. 1954. Special ichthyology, second edition. Ministry of Culture, U.S.S.R. Published for the National Science Foundation, Washington, D. C. and the Smithsonian Institution by the Israel Program for Scientific Translations, Jerusalem 1961.

Norris, K. S. 1957. Second record of the green sturgeon in southern California. *Calif. Fish Game* 43:317.

Okada, Y. 1955. *Fishes of Japan*. Maruzen Co. Ltd., Tokyo. 434 p.

ODFW and WDF (Oregon Department of Fish and Wildlife and Washington Department of Fisheries). 1976. *Columbia River fish runs and fisheries 1957-1975*. Volume 2, Number 1.

ODFW and WDF. 1988. *Columbia River fish runs and fisheries 1960-1987*.

ODFW. 2000. Oregon Department of Fish and Wildlife green sturgeon files. Produced by Steve King, ODFW, in response to an Oregon Public Records Act request.

ODFW. 2000a. Oregon Department of Fish and Wildlife coastal sturgeon tagging data, 1997-2000.

ODFW. 2000b. Oregon Department of Fish and Wildlife World Wide Web electronic publication. www.dfw.state.or.us.

Otaki, K. 1907. The common sturgeon of Hokkaido. *Transactions of the Sapporo Natural History Society* 2(1): 79-84.

Pacific Fisheries Information Network (PacFIN). 2001. Data provided by John Harms, National Marine Fisheries Service.

Parks, N. B. 1978. The Pacific Northwest commercial fishery for sturgeon. *Marine Fisheries Review* 40(7): 17-20 (1978).

Parsley, M. J. and L. G. Beckman. 1994. White sturgeon spawning and rearing habitat in the lower Columbia River. *North American Journal of Fisheries Management* 14(4): 812-827 (1994).

Partridge, F. 1983. River and stream investigations. Kootenai River fisheries investigations. Job Completion Report, Project F-73-R-5. Idaho Department of Fish and Game.

Pearcy, W. G. and S. S. Myers. 1974. Larval fishes of Yaquina Bay, Oregon: A nursery ground for marine fishes? *Fishery Bulletin* 72(1): 201-213.

Percy, K. C., C. Sutterlin, D. A. Bella, and P. C. Klingeman. 1974. Descriptions and information sources of Oregon estuaries. Oregon State University, Corvallis, 294 pp.

Pruter, A. T. and D. L. Alverson. 1972. The Columbia River Estuary and adjacent ocean waters, bioenvironmental studies. U. S. Atomic Energy Commission, Division of Technical Information. University of Washington Press, Seattle, WA. pp. 81-120.

Puckett, L. K. 1976. Observations on the downstream migrations of anadromous fishes within the Eel River System. California Department of Fish and Game Memorandum Report, 34 pp.

Pycha, R. L. 1956. Progress report on white sturgeon studies. *California Fish and Game* 42(1): 23-35 (1956).

- Radtko, L. D. 1966. Distribution of smelt, juvenile sturgeon, and starry flounder in the Sacramento-San Joaquin Delta with observations on food of sturgeons. *In* Turner, J. L. and D. W. Kelley (ed.) Ecological studies of the Sacramento-San Joaquin Estuary, Part II; California Department of Fish Game Fish Bulletin 136, pp 115-119.
- Ratti, F. 1979. Natural resources of the Rogue Estuary. Estuary Inventory Report 2(8), Oregon Department of Fish and Wildlife.
- Reshetnikov, Y. S., N. G. Bogutskaya, E. D. Vasil'eva, E. A. Dorofeeva, A. M. Naeska, O. A. Popova, K. A. Savvaitova, V. G. Sideleva, and L. J. Sokolov. 1997. An annotated check-list of the fresh water fishes of Russia. *J. Ichthyol.* 37(9): 687-736.
- Reynolds, F. L., T. J. Mills, R. Benthin, and A. Low. 1993. Restoring Central Valley streams: a plan for action. California Department of Fish and Game, Inland Fisheries Division, Sacramento, California. 129 p.
- Ricker, W. E., 1975. Computation and interpretation of biological statistics of fish populations. *Bull. Fish. Res. Board Can.* 191, 382 p.
- Rochard, E., G. Castelnaud, and M. Lepage. 1990. Sturgeons (Pisces: Acipenseridae): Threats and prospects. *Journal of Fish Biology* 37 (Supplement A): 123-132 (1990).
- Roedel, P. M. 1941. A sturgeon in Southern California waters. *California Fish and Game* 27(3): 191 (1941).
- Roussow, G. 1957. Some considerations concerning sturgeon spawning periodicity. *Journal of the Fisheries Research Board of Canada* 14(4): 553-572 (1957).
- Roye, C. 1979. Natural resources of Coos Bay Estuary. Estuary Inventory Report 2(6), Oregon Department of Fish and Wildlife.
- Rueth, J. C., T. T. Kisanuki, and J. C. Polos. 1992. Annual report, Klamath River fisheries Assessment program 1990 and 1991. U. S. Fish and Wildlife Service, Coastal California Fishery Resource Office, Arcata, California.
- Sameulson, C. E. 1973. Fishes of South Humboldt Bay, Humboldt County, California. Unpublished M.S. Thesis, Humboldt State University, Arcata, CA 94 pp.
- Schaffter, R. G. 1997. White sturgeon spawning migrations and location of spawning habitat in the Sacramento River, California. *California Fish and Game* 83(1): 1-20 (1997).
- Schreiber, M. R. 1960. Observations on the systematics of juvenile white sturgeon and green sturgeon. California Department of Fish and Game, Inland Fisheries Administrative Report 60-15.
- Scott, W. B. and E. J. Crossman. 1973. Freshwater fishes of Canada. *Fisheries Research Board of Canada Bulletin* 184: 90-91.
- Semakula, S. N. and P. A. Larkin. 1968. Age, growth, food, and yield of the white sturgeon (*Acipenser transmontanus*) of the Fraser River, British Columbia. *Journal of the Fisheries Research Board of Canada* 25(12): 2589-2602 (1968).
- Sheehan, R. J. and J. L. Rasmussen. 1993. Large rivers. pp. 445-468. *In* C. C. Kohler and W. A. Hubert (ed.). Inland fisheries management in North America. American Fisheries Society Bethesda, MD.
- Shmidt, P. Y. 1965. Fishes of the Sea of Okhotsk. Academy of the Sciences of the U.S.S.R., Transactions of the Pacific Committee, Vol. VI. Translated by Israel Program for Scientific Translations, Jerusalem.

- Skinner, J. E. 1962. An historical review of the fish and wildlife resources of the San Francisco Bay Area. California Department of Fish and Game, Water Projects Branch Report No. 1, 226 pp.
- Skinner, J. E. 1972. Ecological studies of the Sacramento-San Joaquin Estuary. California Department of Fish and Game Delta Fish and Wildlife Protection Study, Report No. 8.
- Skinner, J. E. 1982. Fish and wildlife problems and study requirements in relation to North Coast water development. California Department of Fish and Game Water Projects Branch Report No. 5.
- Slack, T. and D. Stace-Smith. 1996. Distribution of the green sturgeon rarely seen in British Columbia waters. *A Journal of British Columbia Natural History* 3(1): 39-43.
- Smith, A. K. and J. E. Lauman. 1972. Fish and wildlife resources of the Middle Coast Basin, Oregon, and their water requirements (revised). Oregon State Game Commission, Federal Aid to Fish Restoration Completion Report, Project F-69-R-8, Job Number 15.
- Smith, H. M. 1895. Notes on a reconnaissance of the fisheries of the Pacific Coast of the United States in 1894. *Bulletin of the United States Fish Commission*, Vol. XIV. p. 275-278.
- Snyder, J. O. 1908. The fishes of the coastal streams of Oregon and Northern California. *Bulletin of the Bureau of Fisheries*, Vol. XXVII (1907): 153-189.
- Soldatov, V. K. 1915. A study of the sturgeons of the Amur. Materials for an evaluation of the Russian fishing industry, 3(12), Pt. 2, 95-114.
- Solkolovskaya, T. G., A. G. Sokolovskii, and E. I. Sobolevskii. 1998. A list of fishes of Peter the Great Bay (the Sea of Japan). *J. Ichthyol.* 38(1):1-11.
- Sopher, T. R. 1974. A trawl survey of the fishes of Arcata Bay, California. M.S. Thesis, Humboldt State University, Arcata, CA, 103 pp.
- Standing, J., B. Browning, and J. W. Speth. 1975. The natural resources of Bodega Harbor. CDFG Coastal Wetland Series; 11.
- Starr, R. M. 1979. Natural resources of Siletz Estuary. Oregon Department of Fish and Wildlife, Estuary Inventory Report, Vol. 2, No. 4.
- Stevens, D. E. and L. W. Miller. 1970. Distribution of sturgeon larvae in the Sacramento-San Joaquin River system. *California Fish and Game* 56(2): 80-86 (1970).
- Thompson, K. E., and J. D. Fortune, Jr. 1970. Fish and wildlife resources of the Rogue Basin, Oregon, and their water requirements. Oregon State Game Commission, Federal Aid to Fish Restoration Completion Report, Project F-69-R-6, Job Number 5.
- Tracy, C. 1990. Chuck Tracy, Washington Department of Fisheries, May 25, 1990 Memorandum.
- Turner, J. L. 1966. Introduction to fisheries studies in the Sacramento - San Joaquin Delta. In: Turner, J. L. and D. W. Kelley, editors, *Ecological Studies of the Sacramento-San Joaquin Estuary, Part II*; California Department of Fish Game Fish Bulletin 136, pp 9-14.
- Ueno, T. and K. Abe. 1966. On rare and newly found fishes from the waters of Hokkaido (I) and (II). *Jap. J. Ichthyol.* 13:220-236.
- USFWS (U. S. Fish and Wildlife Service). 1980. Klamath River Fisheries Investigation Program. Annual

Report 1979.

USFWS. 1981. Klamath River Fisheries Investigation Program. Annual Report 1980.

USFWS. 1982. Klamath River Fisheries Investigation Program. Annual Report 1981.

USFWS. 1983. Klamath River Fisheries Investigation Program. Annual Report 1982.

USFWS. 1984. Klamath River Fisheries Investigation Program. Annual Report 1983.

USFWS. 1985. Klamath River Fisheries Investigation Program. Annual Report 1984.

USFWS. 1987. Klamath River Fisheries Investigation Program. Annual Report 1986.

USFWS. 1988. Klamath River Fisheries Investigation Program. Annual Report 1987.

USFWS. 1989. Klamath River Fisheries Investigation Program. Annual Report 1988.

USFWS. 1990. Klamath River Fisheries Investigation Program. Annual Report 1989.

USFWS. 1990a. Notes from green sturgeon workshop held on May 3, 1990 at Humboldt State University, Arcata, CA.

USFWS. 1993. Klamath River Fisheries Investigations 1980-1993 Annual Reports. Arcata, CA.

USFWS. 1995. Sacramento-San Joaquin Delta Native Fishes Recovery Plan. U. S. Fish and Wildlife Service, Portland, Oregon.

USFWS. 1995. Working paper on restoration needs: habitat restoration actions to double natural production of anadromous fish in the Central Valley of California. Volume 3. May 5, 1995. Prepared for USFWS under the direction of the Anadromous Fish Restoration Program Core Group. Stockton, CA.

USFWS. 1999. Trinity River Mainstem Fishery Restoration Environmental Impact Statement/Report.

USFWS. 2000. U. S. Fish and Wildlife Service green sturgeon files. Produced by USFWS in response to a Center for Biological Diversity Freedom of Information Act request.

USFWS. 2000a. USFWS web site. World Wide Web electronic publication.

UBCFC (University of British Columbia Fisheries Centre). 1996. University of British Columbia fish collection, U. B. C., Vancouver, Canada.

Van Eenennaam, A. L., J. D. Murray, and J. F. Medrano. 1999. Karyotype of the American green sturgeon. Transactions of the American Fisheries Society 128: 175-177 (1999).

Van Eenennaam, J. P., M. A. Webb, X. Deng, and S. I. Doroshov. 2001. Artificial spawning and larval rearing of Klamath River green sturgeon. Transactions of the American Fisheries Society 130(1): 159-165 (2001).

Wainwright, D. L. 1965. The fisheries of Humboldt County from 1854 to 1892. (Excerpts From the Humboldt Times). Humboldt Room Collection, Humboldt State University.

Walker, C. R. 1976. Polychlorinated biphenyl compounds (PCB's) and fishery resources. Fisheries (Bull. Am. Fish. Soc.) 1(4): 19-22.

Wang, J. C. 1986. Fishes of the Sacramento-San Joaquin Estuary and adjacent waters, California: A guide to the early life histories. Interagency Ecological Study Program for the Sacramento-San Joaquin Estuary, Technical Report 9.

WDFW (Washington Department of Fish and Wildlife). 1995. 1995 Sport Catch Report. From WDFW web site.

WDFW and ODFW (Washington Department of Fish and Wildlife and Oregon Department of Fish and Wildlife). 1999. Status report, Columbia River fish runs and fisheries, 1938-1998.

Watts, J. W. and C. E. Melcher. 1997. 1997 Tillamook Bay sturgeon tagging. Oregon Department of Fish and Wildlife. Columbia River Management. Clackamas, Oregon.

Watts, J. W. and M. V. Hunter. 1999. The 1998 Lower Columbia River and Buoy 10 recreational fisheries. Oregon Department of Fish and Wildlife, Fish Division, Columbia River Management.

Whisler, J., T. Neill, and K. Melcher. 1999. 1998 sturgeon tagging project in select coastal estuaries. Oregon Department of Fish and Wildlife. Columbia River Management. Clackamas, Oregon.

Wilimovsky, N. J. 1954. List of the fishes of Alaska. Stanford Ichthyol. Bull. 4(5)279-294.

Wilimovsky, N. J. 1964. Inshore fish fauna of the Aleutian archipelago. Proc. Alaska Sci. Conf. 14: 172-190.

Wydoski, R. S. and R. R. Whitney. 1979. Inland fishes of Washington. University of Washington Press, Seattle, WA, 220 pp.

Young, A. T. and M. E. Foster. 1990. Sturgeons. U. S. Department of Agriculture, AIC Series #4.